NAVAL POSTGRADUATE SCHOOL

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THESIS

KEEPING CURRENT AND INCREASING THE EFFECTIVENESS
OF THE DECISION-MAKING PROCESS AND THE
INTEROPERABILITY IN THE DIGITAL AGE: GEOSPATIAL
INTELLIGENCE AND GEOSPATIAL INFORMATION SYSTEMS'
APPLICATIONS IN THE MILITARY AND INTELLIGENCE FIELDS
FOR THE MEXICAN NAVY

by

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December 2008

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Second Reader:	Sean Everton

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13. ABSTRACT (maximum 200 words)

The birth of the digital era — full of new technologies and information systems that increase as time goes by — has forced the military to embrace these innovations so that they do not lose effectiveness or become obsolete when compared with other countries' armed forces. One of these innovations is the Geospatial Information Systems (GIS), which is the result of geography's evolution from its application for naming and delineating the boundaries of countries, seas, and rivers. Modern day applications of this science have transformed it into a more scientific, mathematical, and technological one, which is a powerful tool for GEOINT analysts, and support of the decision-making process in the intelligence and military fields.

This thesis introduces the GEOINT-process-model and the main GIS applications in the military and intelligence fields. A practical scenario that embraces a SOF operation is developed through use of the GEOINT process and ArcGIS software. Furthermore, this thesis presents a preliminary approach for the Mexican Navy to embrace the use of GIS and GEOINT.

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I. INTRODUCTION

> I am an avid believer in the power of GEOINT [Geospatial intelligence] and the benefits that are derived by working jointly to help our nation's decision-makers and warfighters address critical intelligence challenges. By working together, we will build on past accomplishments and lessons learned to ensure that we may continue to provide GEOINT on which our national leaders, military and other valued customers depend. This will ensure even greater security for our nation and our allies.
>
> — **Robert B. Murret**, Vice Admiral, U.S. Navy, Director of the National Geospatial-intelligence Agency (NGA) and Functional Manager of the National System of Geospatial intelligence (NSG).

A. OVERVIEW

The birth of the digital era and the advent of a new millennium — full of new technologies and information systems that increase as time goes by — has pushed the military, worldwide, to seize on these innovations so that they do not fall behind or become ineffective. That is primarily because a military that does not improve its information systems could become obsolete when compared with other countries' armed forces.

One of these innovations is the Geospatial Information Systems (GIS), which is defined as "a computer-based, dynamic mapping system with spatial data-processing and querying capabilities."[1] It provides support to decision-makers in performing geospatial analysis[2] in almost every field. The fields in which geospatial analysis can be applied are almost infinite; they range from

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[1] Wilpen L. Gorr and Kristen Seamens Kurland, *Learning and using Geographic Information Systems: ArcGIS Edition* (Boston, Mass: Thomson Course Technology, 2007), 4.

[2] "Spatial analysis" sometimes is taken as a tool in developing "geospatial analysis;" as in the case of the "spatial analyst" tool in the ArcGIS program. It is important to note that when referring to the analysis *per se* "Geospatial analysis" and "spatial analysis" are synonyms and interchangeable.

environmental, architectural, social, economical, and medical issues to political, national security, communications, and of course, military issues, just to name a few.

In spite of the fact that GIS is somewhat new, geospatial analysis, which is the foundational discipline of GIS, is not; in fact humankind has been thinking "spatially" since it started reasoning about its own allocation and the allocation of other things with respect its own position. Then, when humans evolved from a nomadic to a sedentary way of life, they started to apply geospatial analysis empirically in the settlement of villages; looking for the best environment to live and to develop, given its geographic situation. In fact, humans used mapping disciplines, now known as cartography, long before the time of Christ. The specific name of the first map and its date of creation are not clear, because there are many claimants for this honor, for example, the Konya Town map, Figure 1, displayed in a Tonya, Turkey museum dates back from 6200 B.C.[3] and it is said that that is the construction project of that town.

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[3] "Milestones: Section 2. Pre-1600,"
http://www.math.yorku.ca/SCS/Gallery/milestone/sec2.html (accessed date 8/8/2008).
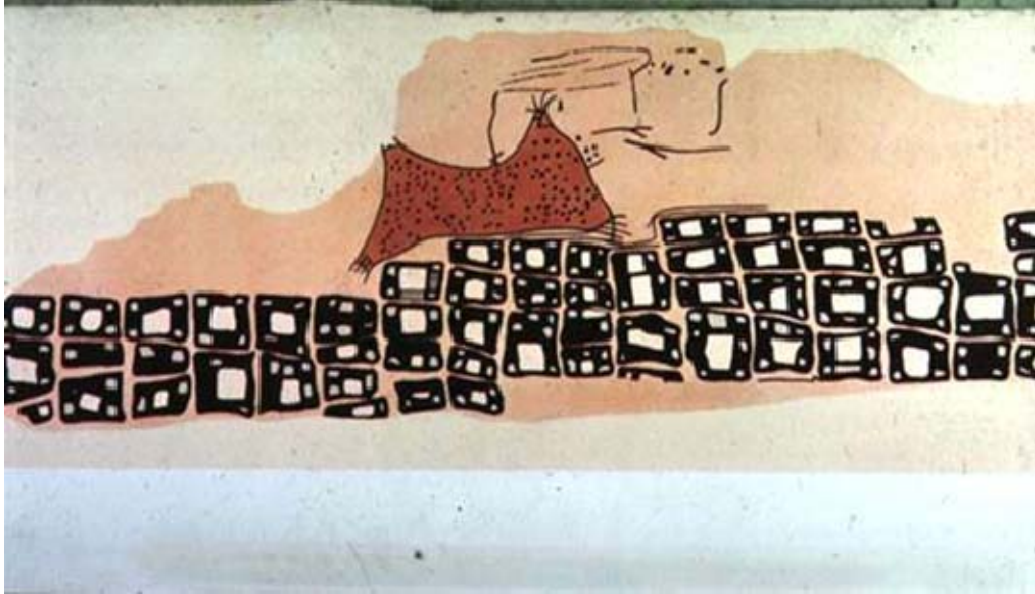
Figure 1.   Konya Town Map, 6200 B.C.

Cartography then leaded to the foundations of geography. The later is described as "the study of the earth and its features, inhabitants, and phenomena." The foundations of geography as a science can be traced back to the ancient cultures of the Greeks and the Chinese. Anaximander of Miletus (c. 610 B.C.-c. 545 B.C.) is considered the true founder of geography; he is credited with the invention of the gnomon, which was an instrument to measure latitude. In addition, he is also credited with the prediction of eclipses.[4]

Even though geography had long been applied "naturally" in the everyday tasks in disciplines such as environmental, architectural, and military planning, in the past, the common end for using geography usually consisted in naming and allocating countries and/or cities, seas, rivers, and some other geographic characteristics of places in the planet.[5]

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[4] Wikipedia contributors, "Geography," Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/wiki/geography#history_of_geography?oldid=230501784 (accessed date 8/8/2008).

[5] Harm J. De Blij, *Why Geography Matters: Three Challenges Facing America: Climate Change, the Rise of China, and Global Terrorism* (New York, N.Y: Oxford University Press, 2007), 4.

However, in recent times "…geography itself has gone through several transformations..." Some decades ago, geography "…had become more scientific, even mathematical." In addition, geospatial analysis started to be applied in a more methodological sense: by establishing connections and interactive combinations of data from different fields for planning or solving problems. Nowadays geography and geospatial analysis have also become "…more technological, and not for nothing does the now-common acronym of GIS stands for Geographic Information Systems."[6]

GIS allows the problem-solvers the data visualization of the factors, which affect a given problem, which are mapped systematically to facilitate their analysis. GIS visualization may allow the problem-solvers or decision-makers the application of geographic reasoning (geospatial analysis) so that they can find patterns or suitable data on which to base their decisions.

The "final product" of geospatial analysis, which is a map, can provide a very powerful support to the decision-making process because the geo-analyst is able to provide the visual representation of a magnificent amount of information that is spatially-processed and organized. That visual representation of the factors influencing the problem or the alternative solutions would provide the decision-makers with a great support in making a final decision. Blij would concur: "…at just a glance, a map can reveal what no amount of description can. Maps are the language of geography, often the most direct and effective way to convey grand ideas or complex theories."[7]

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[6] Harm J. De Blij, *Why Geography Matters: Three Challenges Facing America: Climate Change, the Rise of China, and Global Terrorism* (New York, N.Y: Oxford University Press, 2007), 4.

[7] Harm J. De Blij, *Why Geography Matters: Three Challenges Facing America: Climate Change, the Rise of China, and Global Terrorism* (New York, N.Y: Oxford University Press, 2007), 23.

Because the concept of time is crucial in analyzing a given problem, temporal analysis is often embedded in geospatial analysis. Hence, temporal analysis is given by the "…attempt to understand items that are related by or limited in time, as well as time patterns within data."[8]

The relationship between time and space was addressed by the German philosopher Immanuel Kant (1724-1804), who is regarded as one of the most influential thinkers of modern Europe.[9] Kant contributed to placing geography as a science in the 1700s and provided the philosophical foundation of the human knowledge given by observation. He argued that human-thought bases reasoning about a given situation on three interrelated aspects: *Topic*, *Time*, and *Space*. *Topic* refers to the area of study in where the situation has to be placed in order to reason about it, in accordance with its nature and, at the same instance, that situation has to be positioned both in *Time* and in *Space*. Hence according to Kant:

> Understanding of geographical situations is always improved when we consider their development over time. Just as there are geographers who wish to study the cultural landscapes of former times without necessarily using their knowledge to illuminate contemporary conditions, so historians should not neglect the study of differences between places. Here the individual sciences overlap each other.[10]

Military planning has always involved geospatial analysis. Just to give a basic example, regarding the geographic situation of forces involved in a conflict, the common questions to solve would include:

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[8] Michael Ronczkowski, *Terrorism and Organized Hate Crime: Intelligence Gathering, Analysis, and Investigations*, 2nd ed. (Boca Raton: CRC Press, 2007), 84.

[9] Wikipedia contributors, "Immanuel Kant," Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/wiki/immanuel_kant?oldid=230940249 (accessed date 8/9/2008).

[10] Arild Holt-Jensen, *Geography, History, and Concepts: A Student's Guide*, 3rd ed. (London; Thousand Oaks, Calif: Sage Publications, 1999), 228, http://www.loc.gov/catdir/toc/fy042/99214121.html; (accessed date 6/25/2008).

➢ Where are our forces located?

➢ What are the environmental factors, given by the geospatial situation, which could affect or influence my forces in the operational area?

➢ Where are the enemy forces located?

➢ How does the geospatial environment affect them?

The first question is not a large issue anymore, thanks to the advances in the Global Positioning System (GPS) and other systems that allow integration of the information about the allocation of our own forces in real time. We can now say that the geospatial analysis given by the allocation of our own forces is being done "on the fly" and does not require much effort from military commanders.

The ability to answer the first question allows militaries to focus on the last three, which are related to the enemy and more difficult to answer. If it is difficult to allocate actual positions of the enemy forces, it is even more difficult to predict a future enemy's geospatial situations. Consequently, military intelligence's fundamental purpose is to eliminate the planners' uncertainty often given by questions about the enemy. In that field geospatial analysis helps the analyst to combine a large amount of information about the enemy placed in space and in time. That is why geospatial analysis in the military and intelligence arena is now considered a component of Geospatial intelligence (GEOINT).

U.S. National Geospatial-intelligence Agency (NGA) defines GEOINT as "the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth."[11] As every other intelligence discipline, the military has been performing GEOINT as a "complement of" and "complementing from"

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[11] National Research Council (U.S.) and others, *Priorities for GEOINT Research at the National Geospatial-Intelligence Agency* (Washington, DC: National Academies Press, 2006), 5, http://www.nap.edu/catalog/11601.html (accessed date 8/7/2008).

Human intelligence (HUMINT), Signals intelligence (SIGINT), Measurement and Signatures intelligence (MASINT), and Open-Source intelligence (OSINT).[12]

Still, the integration of the aforementioned disciplines in the intelligence process is often an enormous analytical work for the intelligence community since military commanders expect to receive accurate and timely GEOINT as support for their final decision. Therefore, new technologies are providing the decision-makers with powerful GIS that support the integration of the information products in the GEOINT process.

Similarly, every country around the globe has recognized the high level of relevance of geospatial analysis for every discipline; consequently, governments of many nations are now exploiting GIS and assigning considerable amounts of resources for research, development, and application of GIS to many disciplines.

Nevertheless, military forces are now dealing with the fact that the control of new technologies and information systems are no longer being used exclusively for military. Non-state-actors such as insurgents, terrorists, as well as organized criminal organizations have taken advantage of these innovations sometimes in a more effective way than the military.

Hence, military institutions worldwide are compromised in making the most of new analytical technology. They have been doing so, on the one hand, by exploiting commercial analytical tools through fitting-out those innovations to the military field and effectively training the military decision-makers. On the other hand, by means of effective research and development work, some militaries have created customized military analytical tools, which support specific GEOINT tasks. For example, many government and military institutions have created structures to take the lead in GIS, or, at least, to stay abreast of the commercial enterprises. Among the governments that are taking the lead on GIS we can find the United Kingdom with the Defense Geographic and Imaginary intelligence

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[12] United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence: Geospatial Intelligence (GEOINT) Basic Doctrine* (Bethesda, MD: National Geospatial Intelligence Agency, 2006), 10, http://www.nga.mil/NGASiteContent/StaticFiles/OCR/geopub1.pdf (accessed date 5/30/2008).

(DGI) Agency –that agency is part of the Defense Intelligence Joint Environment (DIJE), which is a branch of the U.K. Ministry of Defense. "Australia's lead GEOINT agency is the Defense Imagery and Geospatial Organisation [*sic*] (DIGO)." [13]

Likewise, in the cases of Canada and the U.S., the former relies on the Directorate of Geospatial intelligence (D Geo Int)[14] and the later relies on the National Geospatial-intelligence Agency (NGA), and NGA comprises the National System for Geospatial intelligence (NSG).[15]

The GEOINT systems of the entities aforementioned base their effectiveness, on the one hand, by the integration of their GIS in a database in which the GEOINT analyst of a given operational force has controlled-access to the required information products for the execution of the tasks of that unit's components. On the other, that effectiveness is also given by the decentralization of the GIS and that is done by providing the operational forces with the tools to execute their own GEOINT process in almost "real time." That allows the GEOINT analyst to be able to provide timely and effective GEOINT to the operational commander and his/her subordinated units "on the field." Additionally, the "integration of the information products" and the "decentralization of the GIS" provide the GIS with actualized GEOINT "on the fly."

Even though Mexico's economy, military power, and foreign policy differ from the countries mentioned previously, it, too, faces global and regional threats that affect it internally. For example, in the global arena, Mexico faces threats to national security as in the case of terrorism, In addition, in the internal and regional arena, it faces threats such as drug-trafficking and arms smuggling to name just two of the most important threats.

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[13] United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence: Geospatial Intelligence (GEOINT) Basic Doctrine* (Bethesda, MD: National Geospatial Intelligence Agency, 2006), 43-44, http://www.nga.mil/NGASiteContent/StaticFiles/OCR/geopub1.pdf (accessed date 5/30/2008).

[14] Ibid., 44.

[15] Ibid., 4.

Nowadays, organized crime and drug-trafficking are considered the most serious threat to Mexican national security due to the increasing levels of drug-related-murders and guerrilla-like tactics used by those criminal organizations. Consequently, Mexican military institutions play a significant role in executing joint operations with other federal institutions against those threats.

It is worth mentioning that the Mexican Navy is somewhat unique because it is forced to develop manifold and diverse tasks executing its administrative and operational responsibilities. It is the only Mexican institution capable of preserving the rule of law and protecting the state in Mexican seas, acting as both a Navy and a Coast Guard. Moreover, it has jurisdiction over the Isles and inland in the continental-shoreline-strip. Hence, in order to cover its jurisdiction the Mexican Navy executes diverse tasks that involve sea, land, and air operations.

Mexican Navy decision makers are well aware of the complex situation with which they are dealing; consequently, they have devoted a significant part of the Navy's resources and efforts to research and development in the military field. Such as the case of the design and construction of Navy vessels, optronic-fire-control-directors, radars, and night vision devices, to name just a few.[16]

The Mexican Navy is knowledgeable of the changing global security environment often given by non-state-actors that are using new technologies and tactics to harm the rule of law and the sovereignty of the States. Consequently, the Mexican Navy has seized on new military technologies as well as making strides in improving its doctrines, education programs and organizational structures to give commanders and other personnel the capability of facing these new threats more effectively.

As related to GIS, one of the technological, structural, and operational achievements in the Mexican Navy was that it, along with the *Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación* SAGARPA

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[16] SEMAR, "Ciencia y Tecnología. Investigación," Secretaria de Marina, Armada de México, http://www.semar.gob.mx/investigación/index.html (accessed date 8/1/2008).

(Secretariat of Agriculture, Livestock, Rural Development, Fishing and Food) was put in charge of the installation, custody, and operation of the satellite station ERMEXS. The Mexican president, at that time, Vicente Fox inaugurated that station in 2003.[17]

ERMEXS was the cornerstone of the Mexican Navy's GEOINT capabilities because in 2004 that institution created the *Subseccion de Información Satelital* SIS (Subsection of Satellite Information) as a part of the section of intelligence in the structure of the Navy General Staff. That new responsibility in the intelligence section of the General Staff demanded trained people and a Geospatial Information System (GIS) for execution of it. Therefore, people in the GEOINT group of the SIS were trained in remote sensing, visual analysis, and the geospatial analytical software that the SIS now counts on as a part of its GIS, which are ERDAS and ArcGIS packages.[18]

The new support in the intelligence structure of the Mexican Navy has resulted in a significant improvement of the effectiveness of its operational units. For example, in July 2008 Mexican deputies emphasized the outstanding work of the Mexican Navy Intelligence System and congratulated the Secretary of the Navy. In that event, the policy makers praised the recent achievement made by the Mexican Navy, which was the interception and seizure of a ten-ton Colombian submarine that was trafficking with approximately six tons of cocaine in Mexican waters. The successful operation was executed thanks to the effective execution of interdiction operations at sea by Navy vessels in support of Navy intelligence.[19]

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[17] SEMAR, "ERMEXS," Secretaria de Marina, Armada de México, http://www.semar.gob.mx/ermexs/ERMEXS.htm (accessed date 8/2/2008).

[18] Information achieved from a personal communication with the Chief of the GEOINT Group of the Mexican Navy General Staff.

[19] "Felicitan Diputados a SEMAR Por Captura De Narco Submarino," *El Financiero* 2008, no. 7/17/2008, http://www.elfinanciero.com.mx/ElFinanciero/Portal/cfpages/print.cfm?docId=132801 (accessed date 8/5/2008).

B. PROBLEM IDENTIFICATION

GEOINT and GIS has proved to be a significant tool in the performance of the Mexican Navy intelligence. However, because GEOINT is a relatively new discipline in the Mexican Navy, which is just starting to evolve, it is still mandated that decision makers and analysts are well versed about the almost limitless applications that GEOINT and GIS have in the intelligence and military fields.

In addition, GIS and GEOINT capabilities in the Mexican Navy are concentrated in the General Staff. This means that the operational forces on the ground still do not rely on the same analytical software (as in the case of the SIS) nor rely on the required GEOINT analysts to develop their GEOINT process independently, as is demanded by the ever-changing environment.

Tasks in the everyday performance of the Mexican Navy operational Forces require timely coordination and effective decision maker responses; however, because these tasks are manifold and diverse, Mexican Navy operational commanders face a tremendous endeavor when it comes to analyzing and solving the implicit problems brought into play. The lack of timely and accurate decisions in solving those problems leads to a waste of human and material resources as well as to a performance that an effective execution of the GEOINT process and use of GIS would certainly improve.

C. PURPOSE AND SCOPE

This thesis's main purpose is to analyze GEOINT and its process, as well as the GIS applications in the military and intelligence field that can be exploited by the Mexican Navy in order to make the most efficient use of GEOINT and GIS abilities. In addition, this work will provide a preliminary approach to drive the enhancement of the Mexican Navy GEOINT capabilities.

This thesis will begin with a description and conceptualization of GEOINT and its process within the intelligence mainstream. Later, this study will highlight some of the main GIS applications in the military and intelligence fields that could be exploited by the Mexican Navy. A practical scenario will be developed where

the GEOINT process and ArcGIS software will be applied to show how they are excellent tools for the analysis and which final products support the decision-making process.

The study of the application of GIS will focus on the use of ArcGIS geospatial analytical software, due to the acceptance of this product in the intelligence and military community as well as the fact that this is one of the software products used by the GEOINT analysts in the Mexican Navy. The scope of this thesis embraces the Mexican Navy decision makers and the intelligence system of the institution. However, due the high relevance of the topic in recent times for the intelligence and military institutions worldwide, this work may also be useful for people from those communities who want to learn about GEOINT and its process as well as GIS applications. This work will offer to them an approach that is focused on the operational requirements of military institutions rather than commercial endeavors, which can be found in abundance in the literature currently available about the topic. In addition, this research may be valuable for the students of the course on Dark Networks and CORE (Common Operational Research Environment) Lab users of the Defense Analysis Department in the Naval Postgraduate School as a complement to their learning.

D.   HYPOTHESES AND SPECIFIC RESEARCH QUESTIONS

1.   Hypothesis:

a.   By understanding the GEOINT process and GIS applications in the military and intelligence fields and enhancing its GEOINT capabilities, the Mexican Navy would improve its everyday tasks and would seize on the military and intelligence applications of GIS. Furthermore, that may put the Mexican Navy in the vanguard on GEOINT in Mexico.

2.   Research Questions:

In order to prove the aforementioned hypotheses the present work will seek to answer the following questions:

a.   What is geospatial analysis?

b.   What is GEOINT all about?

c.   Which characteristics and applications of GEOINT are relevant in general to the intelligence and military field and specifically for the Mexican Navy?

d.   How can these applications improve the decision making process in the Mexican Navy?

e.   What are the current Mexican Navy GEOINT capabilities?

f.   How can the Mexican Navy GEOINT capabilities can be enhanced to make the most of that discipline?

g.   What would be the benefits of such an implementation?

E.   METHODOLOGY, THEORETICAL FRAMEWORK, AND THESIS ORGANIZATION

"Mixed Methods" approach will be used to support this research. The qualitative part of this thesis will predominate in the description of GEOINT and conceptualization of related fields and terms in the first three chapters. In addition, the qualitative approach will predominate in the chapters V, and VI when it will be offered a preliminary approach for the enhancement of Mexican Navy GEOINT capabilities and "conclusion and recommendations" respectively. The quantitative section will be in the development of the GEOINT process and the application of geospatial analysis in solving the hypothetical scenario presented in chapter IV. However, a combination of both approaches (mixed methods) will be seen throughout this thesis.

In this thesis, Geospatial and Temporal Analysis theory and concepts will be used, which are taught in the "Dark Networks" course, the directed study on "Spatial and Geostatistical Analysis for GEOINT," and the training on "Working

with ArcGIS Spatial Analyst for Geospatial intelligence." The first two ones are taught in the defense analysis department at NPS and the last one at the ESRI Learning Center in Redlands, CA.

"Geospatial intelligence (GEOINT) Basic Doctrine," publication 1-0 will be taken as one of the main references to conceptualize GEOINT.

In working with GIS and other analytical applications, the work and research will be developed in the CORE (Common Operational Research Environment) Lab of the Defense Analysis department of the Naval Postgraduate School that relies on ArcGIS, diverse analytical software, and support required.

In this thesis, it will be described GIS, geospatial analysis, and GEOINT in some detail and their applications in general in the military and intelligence fields that can be exploited by the Mexican Navy. The description mentioned may be a guideline that will show how the Mexican Navy would benefit from GEOINT and GIS. In that context, a guideline model of the GEOINT process will be presented to execute effectively the tasks given in that discipline. The description of the GEOINT process model will be reinforced by a practical application using ArcGIS software to analyze "geospatially" a given hypothetical scenario that will involve an operation with Mexican Navy Special Operations Forces. Finally, a preliminary approach of enhancement of the Mexican Navy GEOINT capabilities will be presented and conclusions and recommendations will be offered. Hence, in order to provide these concepts, this thesis is organized as follows:

Chapter I presents the overview of GIS, geospatial analysis, and GEOINT. This chapter also identifies the problem to be addressed by this work and provides the hypotheses to be proved.

Chapter II will describe GEOINT, its process, and related concepts. This chapter also will present how GEOINT is considered in one of the models of war more recently coined, which is Network-Centric Warfare (NCW). In this chapter, a GEOINT process model will be presented, which will provide a guideline of the tasks involved in GEOINT to be developed by the intelligence and military community.

Chapter III will present an overview of some of the GIS and ArcGIS analytical software toolsets. In addition, this chapter will present some of ArcGIS' specific practical applications in the military and intelligence fields for the Mexican Navy.

Chapter IV will present a hypothetical scenario, which involves the GEOINT process for executing a rescue operation with the Mexican Navy Special Operations Forces (MNSOF). This chapter will provide an example of the use of ArcGIS by the Mexican Navy at the operational level as well as how this software can support the strategic to tactical military levels in the decision making process.

Chapter V. This chapter provides an overview of the status of the Geospatial Analysis field in Mexico and the GEOINT field in the Mexican Navy. In addition, it will provide a preliminary approach that supports the enhancement of the GEOINT capabilities in that institution. This preliminary approach is based on decentralization of the decision making process relative to GEOINT and the integration of the information, as well as training on GEOINT as the key of that enhancement.

Chapter VI will present the conclusions and recommendations of this thesis.

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II. GEOSPATIAL INTELLIGENCE (GEOINT)

Know the Earth…Show the Way
[NGA's motto]

James R. Clapper Jr.

Ret. Lt. Gen. Air Force

A. BACKGROUND

The constantly changing security environment in the regional and global arena has prompted militaries around the world to find means to act in a more proactive way.

> In recent years, targets have gone from static to mobile; time frames, from months to minutes; new forms of denial and deception have been employed; and targets have moved both underground and into civilian and more uncharacterized contexts.[20]

Non-state actors, such as terrorists, insurgents, and organized criminals represent the flexible targets mentioned in the last quote; the military intelligence community around the globe is dealing with the fact that it has to execute the intelligence-process in the most rapid and effective way possible. This would allow the military community to provide the decision makers with timely and accurate intelligence for supporting the final decision.

With that requirement in mind, current military intelligence communities are demanded to count on significant capabilities to handle the intelligence-process. Those capabilities often "…involve high-precision observations, visualization methods, global on-demand information access, permanence of

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[20] National Research Council (U.S.) and others, Priorities for GEOINT Research at the National Geospatial-Intelligence Agency, 11.

records, multi-source data collection, and the capability to add value and densify information content."[21] The execution of these intelligence-process-activities is where GEOINT comes into play.

B.   GEOSPATIAL INTELLIGENCE DEFINITION AND CONCEPTS RELATED

The U.S. National Geospatial-Intelligence Agency (NGA) defines GEOINT as "the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth."[22]

> Geospatial intelligence provides unique knowledge not available by other means that is critical for informed national security decisions. It provides objective, precisely measurable information about the environment and potential adversaries, especially in remote or inaccessible regions.[23]

Furthermore, the applications of GEOINT are manifold in supporting national governments. It provides valuable processed data to the decision makers in many different fields as well as a platform of collaboration between intelligence entities of a given country. NGA grouped the fields in which GEOINT could be applied: Supporting Military Operations, Homeland Security and Civil Support, and Informing Statecraft –the "Informing Statecraft" is now called "Informing National Policymakers" in the new NGA doctrine. Figure 2 illustrates the intelligence collaboration between groups; it also illustrates the overlapping fields of application –those that embrace more than one group.

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[21] National Research Council (U.S.) and others, Priorities for GEOINT Research at the National Geospatial-Intelligence Agency, 11.

[22] Ibid., 5.

[23] United States, National Imagery and Mapping Agency, "Geospatial Intelligence Capstone Concept," National Imagery and Mapping Agency, http://purl.access.gpo.gov/GPO/LPS52092; (accessed date 6/2/2008).

Figure 2.   Overlapping Applications of GEOINT[24]

According to the GEOINT definition, we can identify the three GEOINT elements, which according to the NGA are Imagery, Imagery intelligence (IMINT), and geospatial information, which are defined in the following paragraphs.

Imagery: In GEOINT terms, "imagery" refers to the presentation of features, related objects, or activities "captured" or recorded in a specific place and time that are produced for a great variety of remote sensors like space-based reconnaissance systems, satellites, airborne platforms, or Unmanned

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[24] Retrieved from: NIMA, *Geospatial Intelligence Capstone Concept*, 2002, https://www.hsdl.org/homesec/docs/legis/Geospatial%20intelligence.pdf&code=4983a91d8b48bb 49a6036fb85b724f0d ,(accessed date 7/28/2008.

Aerial Vehicles (UAV). Examples of the data used as imagery are panchromatic imagery, infrared imagery, real-time video, synthetic aperture radar (SAR) imagery, and earth's magnetic data. (It does not include handheld or clandestine photography taken by or on behalf of human intelligence collection organizations).[25]

Imagery intelligence (IMINT): Defined by the NGA as "the technical, geographic, and intelligence information derived through the interpretation or analysis of imagery and collateral materials."[26]

Geospatial Information: Information is often presented in the form of printed or digitalized maps, charts, tables, publications, digital or modeling databases, and photography, among others. This information identifies the geographic characteristics of features and boundaries on the earth such as location, orography, demography, and vegetation among many others. This is "…derived from, among other things, remote sensing, mapping, and surveying technologies; and mapping, charting, geodetic data, and related products."[27]

When a fragment of the GEOINT definition states that GEOINT is "the exploitation and analysis of imagery and geospatial information…" it points toward two of the main activities of the GEOINT discipline. On the one hand, when talking about exploitation and analysis of imagery, it refers to the activity of "imagery analysis." On the other hand, the definition points to the exploitation and analysis of the geospatial information, which is referring to "geospatial analysis." Both activities are very important in the GEOINT process and need to be defined.

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[25] United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence : Geospatial Intelligence (GEOINT) Basic Doctrine*, 51.

[26] Ibid., 7.

[27] Ibid., 7.

Imagery Analysis: It is defined by the NGA as "the science of converting information, extracted from imagery, into intelligence about activities, issues objects, installations, and/or areas of interest."[28] The final result of imagery analysis is IMINT, Figure 3.

Figure 3.   Suspect reactor construction site in Eastern Syria[29]

Imagery analysis, in processing and interpreting imagery, is based on visual analysis that is also called "visualization." Imagery analysts or "photo interpreters" usually employ computers to improve the quantity and quality of the images. Computers now have the capacity to disassemble an image in millions of

28 United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence : Geospatial Intelligence (GEOINT) Basic Doctrine*, 9.

29 Retrieved from: Albright and Brannan (Institute for Science and International Security), Suspect Reactor Site in Eastern Syria: the Site of the September 6 Israeli Raid?, October 2007, http://www.isis-online.org/publications/SuspectSite_24October2007.pdf , (accessed date 8/11/2008).

electronic pulses, or pixels, and then interpreters can use mathematical formulas to manipulate the attributes of the image. As a result, when the image is reassembled, it highlights special features that were hidden before.[30]

Geospatial Analysis: It is defined by the NGA as "the science of extracting meaning from geospatial data [information] and using geographic information systems [GIS] to uncover and investigate relationships and patterns in all forms of geospatial data to answer intelligence and military issues."[31]

Generally, geospatial analysis is considered both a discipline, in non-military-circles, and an activity, within the GEOINT discipline. However, geospatial analysis has the same meaning either way it is taken; the only significant difference is the military connotation when defined as a GEOINT activity. It is also worth mentioning that geospatial analysis is also called spatial analysis.[32]

Time is an important factor to consider in the GEOINT process, and in that respect, *temporal analysis* is given by the "…attempt to understand items that are related by or limited in time, as well as time patterns within data."[33] In addition, this activity is often embedded in the geospatial analysis. As such, much of the GIS software provides the tools to include the *time* factor into the whole analysis.

At present, in the GEOINT arena it is difficult to talk about imagery, geospatial, and temporal analysis as separate entities. That is because they

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[30] Jeffrey Richelson, *the US Intelligence Community*, 5th ed. (Boulder, Colo: Westview Press, 2008), 194.

[31] United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence : Geospatial Intelligence (GEOINT) Basic Doctrine*, 9.

[32] In spite of the fact that "spatial analysis" sometimes is taken as a tool in the development of "geospatial analysis" as in the case of the "spatial analyst" tool in the ArcGIS program, it is important to note that when referring to the analysis *per se,* "Geospatial analysis" and "spatial analysis" are synonyms and interchangeable.

[33] Ronczkowski, *Terrorism and Organized Hate Crime : Intelligence Gathering, Analysis, and Investigations*, 84.

complement each other and are parts of the technological advances in GIS.[34] In spite of the fact that an imagery product offers detailed information for the photo interpreter, when developing imagery analysis, it is still "…only a snapshot, a picture of a particular place at a particular time. . . Imagery is a static piece of intelligence, revealing something about where and when it was taken but nothing about what happened before and after." The image could be compared with another from the past, Figure 4. "But a single image does not reveal everything."[35]

Figure 4.   After (left), date unknown, and before (right), Satellite Imagery of Destroyed Housing in Mbare Township, Harare during "Operation Murambatsvina" (19 May – 21 – July 2005)[36]

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[34] United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence : Geospatial Intelligence (GEOINT) Basic Doctrine*, 7.

[35] Mark M. Lowenthal, *Intelligence : From Secrets to Policy*, 3rd ed. (Washington, DC: CQ Press, 2006), 84.

[36] Retrieved from: http://unosat.web.cern.ch/unosat/freeproducts/zimbabwe/harare_map01-22July2005_low.jpg , (accessed date 8/10/2008).

Conversely, by developing geospatial analysis, analysts are able to measure risks, to establish patterns, and with accurate information and methods, they can, to some degree, predict future situations by establishing "what if scenarios" with the purpose of being more proactive, Figure 5.
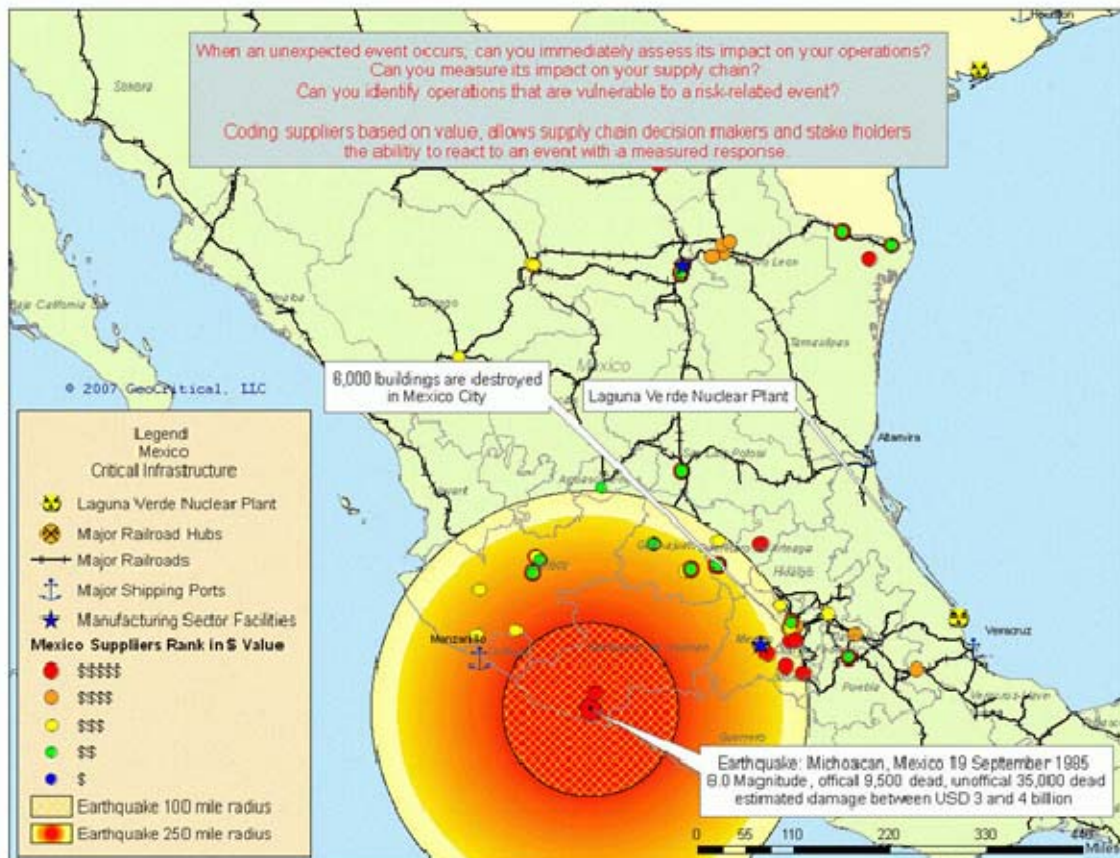
Figure 5. **["What If" Scenario] Impact of potential earthquake on supply network in Mexico. Source: Geocritical, LLC.[37]**

GIS is defined as "a computer-based, dynamic mapping system with spatial data-processing and querying capabilities."[38] These systems are the support to decision makers for performing geospatial analysis. In addition, GIS

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37 GeoCritical. Retrieved from:
http://www.geocritical.com/gc/Earthquakes/tabid/61/Default.aspx , (accessed date 8/10/2008).

38 Gorr and Kurland, *Learning and using Geographic Information Systems : ArcGIS Edition*, 4.

allows the problem solvers the data visualization of factors affecting the problem to solve over the space. That visualization is given by mapping systematically the data to be analyzed.

Advances in GIS, now allow the combination of imagery, geospatial, and temporal analysis in the GEOINT discipline. The software used by the GIS currently has almost limitless capabilities. It not only offers a wide range of tools for visualization, but also a significant number of tools for developing geospatial and temporal analysis. Such is the case of ArcGIS and other GIS software. These may provide the problem solvers or GEOINT analysts not only with excellent support for the application of imagery interpretation but also an analytic tool for developing geographic-temporal reasoning (geospatial and temporal analysis) by looking for a pattern or suitable data, depending on the problem to be solve, in the studied region, Figure 6.
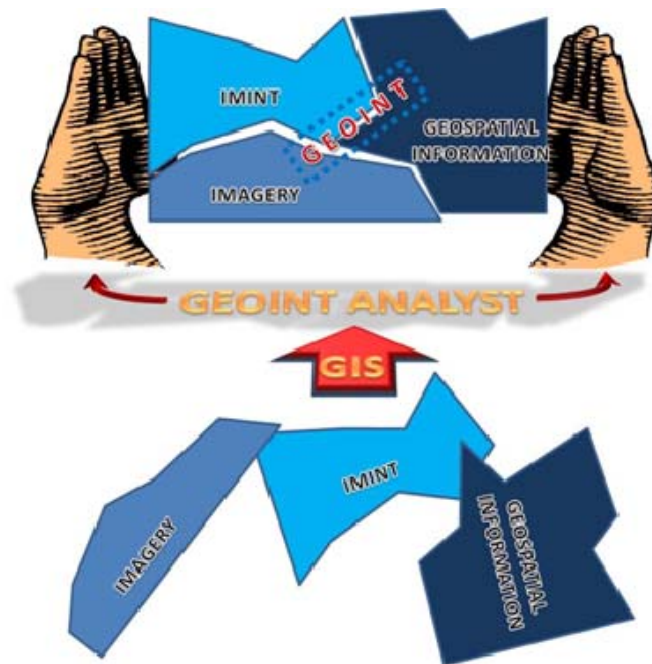
Figure 6.   The three GEOINT elements put together by the analyst by means of GIS

The National Imagery and Mapping Agency (NIMA), now NGA states:

The union of three technological achievements: precision geopositioning, advanced imagery and sensor technologies, and low cost ubiquitous digital data processing, has made possible the convergence of geospatial and imagery analysis into the integrated discipline of geospatial intelligence.[39]

Hence, GIS provides the capability of combining vector-based map layers (digital maps based on lines, points, and polygons), attribute tables (tables with geospatial information) and raster maps (digital imagery). Figure 7.
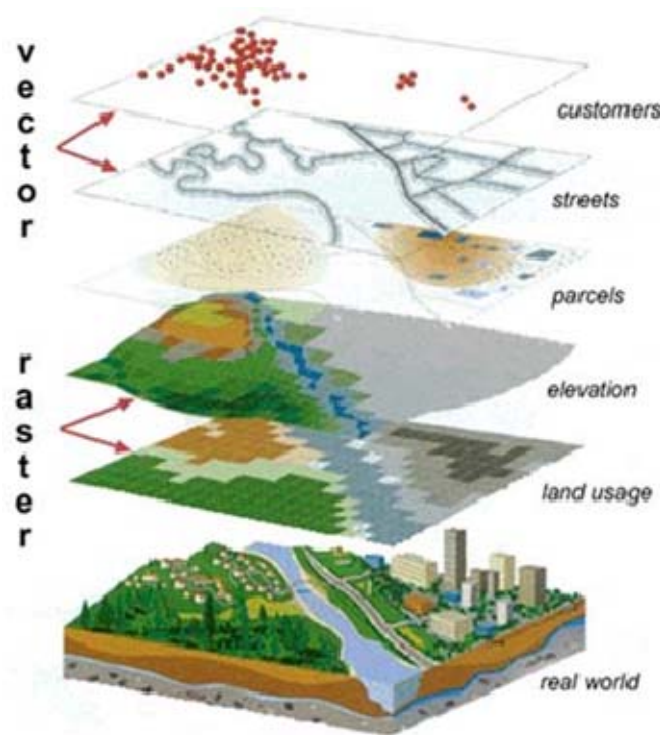
Figure 7.   GIS Data Layering Representation[40]

[39] United States, National Imagery and Mapping Agency, *Geospatial Intelligence Capstone Concept*.

[40] Retrieved from: http://www.ci.ferndale.wa.us/GIS/GIS%20Pic.jpg , (accessed date 8/11/2008).

These GIS powerful capabilities provide the GEOINT analyst with the necessary means for developing a significant part of the GEOINT analysis through the use of image analysis, spatial analysis, geostatistical analysis, data modeling, 3D analysis, and even 4D analysis (when considering time) among many others uses. Figure 8.
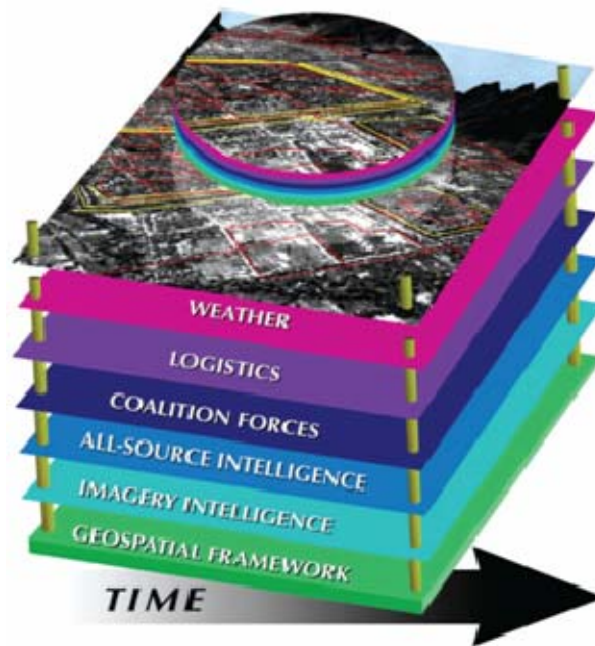
Figure 8.   Fusion in Four Dimensions[41]

C.   GEOSPATIAL INTELLIGENCE AND NETWORK-CENTRIC WARFARE

Once having described GEOINT and related concepts and before entering into the GEOINT process, it is worth noting how this discipline is considered within the Network-Centric Warfare (NCW) arena. Framing GEOINT within the NCW theory will allow for highlighting the importance of GEOINT in one of the most revolutionary concepts of the digital age.

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[41] Retrieved from: NIMA, *Geospatial Intelligence Capstone Concept*, 2002, https://www.hsdl.org/homesec/docs/legis/Geospatial%20intelligence.pdf&code=4983a91d8b48bb 49a6036fb85b724f0d ,date of access; 7/28/2008.

U.S. forces must leverage information technology and innovative network-centric concepts of operations to develop increasingly capable joint forces. New information and communications technologies hold promise for networking highly distributed joint and multinational forces. . . .*42*

The U.S. Director, Force Transformation Office of the Secretary of Defense defines Network-Centric Warfare (NCW) as "…the combination of emerging tactics, techniques, and procedures that a fully or even partially networked force can employ to create a decisive warfighting advantage."[43]

This new concept has been fully addressed by all of the forces within the U.S. DoD in the understanding that its implementation provides warfighting advantage. The concept is based on the combination of "digitalization and networking" of all the forces ranging from the national to the tactical level. This would provide the forces with "a common operational picture [COP] that reduces the ambiguity and confusion of combat to clearly identify the positions of friendly forces and the known positions of the enemy."[44]

GEOINT and GIS play an important role in NCW; the integration of the geographic information about our own forces, the environment, and the enemy forces on the field is achieved by the implementation of a common GIS platform. Furthermore, the imagery collected by the sensors in the area of operations, the IMINT, and the geospatial analysis deliver the required GEOINT to provide an accurate "common picture" to the national down to the tactical level. Figure 9.

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[42] *Secretary of Defense Donald H. Rumsfeld.*

[43] US Director, Force Transformation Office of the Secretary of Defense, "Network-Centric Warfare; Creating a Decisive Warfighting Advantage," http://www.oft.osd.mil/library/library_files/document_318_NCW_GateFold-Pages.pdf (accessed date 8/12/2008).

[44] Ibid.
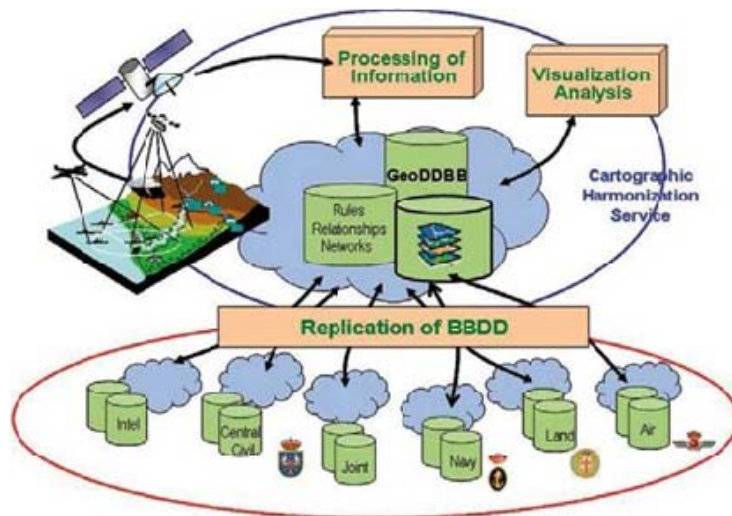
Figure 9.   Representation of GIS and Common Operational Picture in the NCW environment[45]

The integration of information in the NCW would enable warfighters to be more flexible since they would be fed with information about the changing warfare environment. This would not only give them a strategic and informational advantage over enemy forces but it would also reduce their uncertainty, which would release the warfighter from fog of war.

In addition, flexibility acquired by means of effective GIS and GEOINT would provide military forces with dominance of the speed factor in a given conflict. This would be achieved through the visualization of an accurate and timely Common Operational Picture (COP), which would provide a clear notion of the battlespace and situational awareness.[46] Consequently, the forces at the tactical level would be able to make effective decisions following on their current mission and the Rules of Engagement (ROE) without being concerned about the lack of information.

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[45] Retrieved from: http://www.esri.com/industries/defense/user-showcase/def_intel_3.html , (accessed date 8/8/2008).

[46] U.S. Director, Force Transformation Office of the Secretary of Defense, "Network-Centric Warfare; Creating a Decisive Warfighting Advantage," http://www.oft.osd.mil/library/library_files/document_318_NCW_GateFold-Pages.pdf (accessed date 8/12/2008).

In sum, GEOINT plays a significant role in the new theory of war, which is primarily based on NCW concepts. The COP offered by the GEOINT by means of GIS "significantly increases the warfighter's awareness and understanding of tactical and operational situations."[47] At the same time the COP supports the interoperability of the entire force whether they were ground, air, or sea forces and that may provide the decision makers with an integrate analytical tool to develop an effective command and control.

D.   "PUTTING THE PIECES TOGETHER" IN THE GEOINT PROCESS

Because the specialization of intelligence has created new and different intelligence disciplines as well as separate agencies, departments, sections, and groups, there is the danger that in some cases the common goal of the intelligence effort may be lost. As separate entities and different disciplines, they would tend to generate doctrines, processes, and procedures independently. That becomes an interagency conflict when trying to join their intelligence products to the mainstream of the intelligence effort.

Hence, in the specific topic of this study, GEOINT should not be seen as an independent entity disengaged from neither the other intelligence disciplines nor the intelligence process as a whole. Conversely, as every other intelligence discipline, the military has to perform GEOINT as a "complement of" and "complementing from" Human Intelligence (HUMINT), Signals intelligence (SIGINT), Measurement and Signatures Intelligence (MASINT), and Open-Source Intelligence (OSINT), among others.[48]

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[47] Retrieved from: http://www.esri.com/industries/defense/user-showcase/def_intel_3.html , (accessed date 8/8/2008).
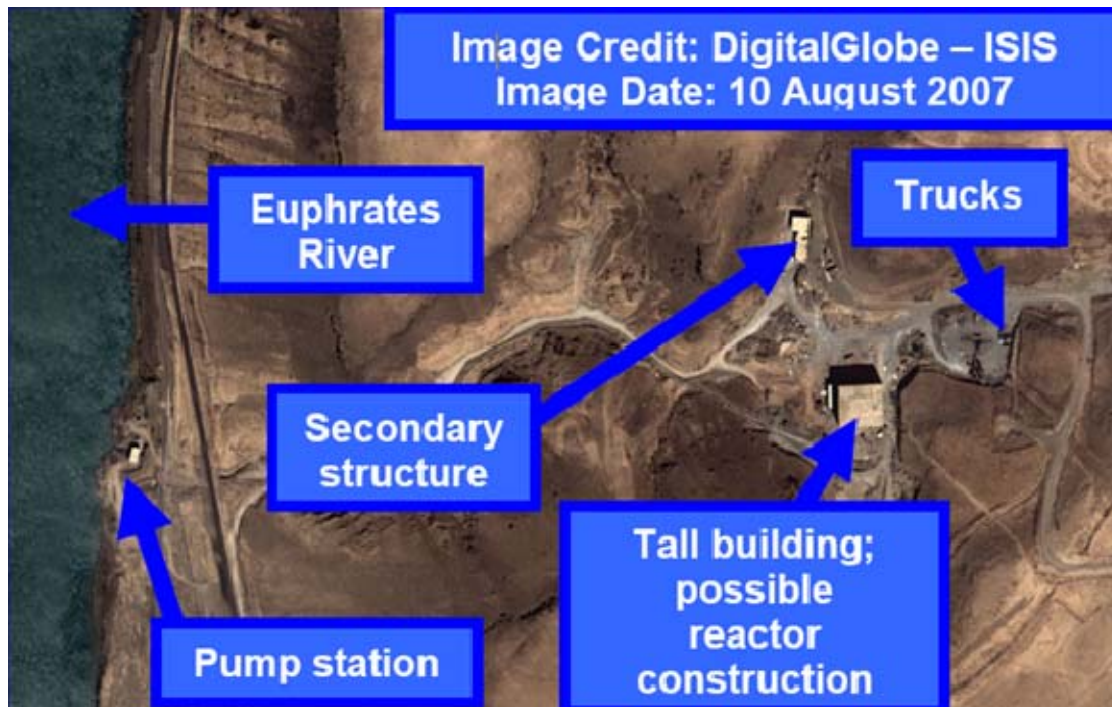
[48] United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence : Geospatial Intelligence (GEOINT) Basic Doctrine*, 10.

Taken together these disciplines are known as Multi-intelligence (Multi-INT),[49] and constitute the entire intelligence effort; therefore, in order to provide the decision makers with adequate information, intelligence analysts must put "all the pieces together," Figure 10.

Figure 10.   Intelligence effort "putting all the pieces together" GEOINT puts together its three elements

Consequently, the tasks of the three different GEOINT activities (namely geospatial analysis, imagery, and IMINT) must be aligned and in accord with the intelligence process; this would enable the coordination and collaboration among analysts from the different disciplines and agencies and it would favor the achievement of the common goal in the intelligence effort. Hence, in presenting the steps of the GEOINT process, they will be reframed by the classic

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[49] For further information about intelligence's disciplines, sub-categories, and sources, refer to: United States, Joint Chiefs of Staff, *Joint Intelligence* (Washington, D.C.: Joint Chiefs of Staff, 2000), I-6, http://www.fas.org/irp/doddir/dod/jp2_0.pdf; (accessed date 7/2/2008).

intelligence process. Some of the basic GEOINT tasks will be offered in every step, in order to provide an analytical model.

As has been learned, along this work, GEOINT consists of three kinds of activities: imagery, imagery intelligence (or imagery analysis), and geospatial analysis. In addition, temporal analysis is embedded in these three activities by adding "the fourth dimension" (time) to the analysis. The activity of imagery mainly consists in collection and production of the necessary images for the development of IMINT and geospatial analysis.

Furthermore, GIS allows the development of two kinds of analytical activities of IMINT and geospatial analysis within the same software platform. In some cases, with the necessary knowledge, one analyst could develop basic imagery interpretation and the geospatial analysis; however, the tools to be used and the approaches to be taken in each case differ somewhat. For example, in developing IMINT, "intelligence on an image may not be self-evident; it may require interpretation by trained photo interpreters who can see things that the untrained person cannot."[50] Independently of how the different analysis were done (jointly or separately) the GEOINT analyst then has "to put all the pieces together" to offer a final GEOINT product in the intelligence effort.

The classic five steps of the intelligence process are Planning and Direction, Collection, Processing and Exploitation, Analysis and Production, and Dissemination. In this process is also worth considering a sixth element (referred as a category in the Joint intelligence Process), which is "Evaluation and Feedback."[51] Figure 11 illustrates the author's GEOINT-process-model, created for this thesis' purposes, which illustrates the basic tasks of the GEOINT analysts, and reframing those tasks within the whole intelligence process. That model would provide the GEOINT analyst with the guideline to synchronize his/her work within the main intelligence effort.

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[50] Lowenthal, *Intelligence : From Secrets to Policy*, 84.

[51] United States, Joint Chiefs of Staff, *Joint Intelligence*, I-6.

Evaluation & Feeback
•Evaluate results in every task
•Receive feedback from the decision-makers and other analysts
•Determine what can be improved
•Go back to previous steps if necessary

GEOINT DISSEMINATION (A)
When it s required to incorporate GEOINT to the Intelligence mainstream:
•Incorporate GEOINT in the "Collection" step of the Intelligence mainstream

GEOINT DISSEMINATION (B)
When just GEOINT is required
•Present GEOINT to the consumers (decision-makers)
•Go back to the Analysis if necessary (to change parameters, constraints, new intelligence...)

GEOINT ANALYSIS
•Integration of IMINT and Geospatial Analysis
•Develop analysis
•Produce GEOINT
•Prepare GEOINT for Dissemination

PLANNING
Geospatial Analysis & IMINT
•Define the Problem
•Define GIS criteria
•Submit required info products (Including intelligence requirements to other disciplines: HUMINT, MASINT, etc...)
Imagery
•Receive request of info products
•Define the means to collect info products
DIRECTION
•*Manage and synchronize efforts during the entire process*

Geospatial Analisys
•Import info products (Including intelligence requirements from other disciplines: HUMINT, MASINT, etc...) (vector-based maps, attribute tables...)
•Build raw dataset
Imagery
•Collect required info products (from databases, remote sensing...)
•Prepare info products
•Export info products
IMINT
•Import Info Products (Raters, photos...)
•Build raw dataset

Geospatial Analysis
•Put raw dataset into GIS
•Process data (georreference [If necessary], synchronize [projection, datum, measures...])
•Build ready-to-use GIS database
IMINT
•Put raw dataset into GIS
•Process data (georreference [If necessary])
•Image interpretation
•Build ready-to-use GIS database

PLANNING AND DIRECTION
DISSEMINATION
COLLECTION
ANALYSIS AND PRODUCTION
PROCESSING AND EXPLOITATION
INTELL PROCESS

Figure 11.   Author's Model of GEOINT Process. It highlights the GEOINT activities (elements) and basic tasks, based on the classic steps of the entire intelligence process.

For presenting a model that is easy to follow,   the GEOINT process model was developed as a cycle with sequential steps that may provide the analysts a guideline for coordination of tasks among GEOINT components as well as to synchronize their work with the intelligence mainstream.

Likewise, with the classic six components of the intelligence process[52] the analyst may take the GEOINT process model as a flexible guideline that allows him/her to return to previous steps when necessary. For example, when the appropriate interpretation of an image is not possible, the photo interpreter may

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[52] Lowenthal, *Intelligence : From Secrets to Policy*, 66.

require requesting a higher resolution image; in doing so, the analyst may be required to return to the collection process. All of this is done "on the fly" in the cycle in order to avoid interrupting the natural workflow of the GEOINT process. In addition, the "planning and direction" part of the process is present in the entire cycle given by the management and synchronization of efforts.

It is worth mentioning that intelligence analysts hardly count on valuable information from all the disciplines; consequently, they have to be trained in developing analytical methods to combine the information they have available in order to fill in the gaps. This allows them to accrue the final intelligence product to be presented to the Commanders, who seek support for the decisions and courses of action, needed to be taken to fulfill their mission or to solve a problem.

Another important consideration is that the "Evaluation and Feedback" component is not a step per se; this is more like a quality control mechanism that the analysts and decision makers involved in the analysis apply all the way around the GEOINT process.

In some cases, just relying on GEOINT could be more than enough for the decision makers, considering that usually the GEOINT analyst relies on intelligence from the other disciplines already at hand. This would be given by the problem presented, or by the availability of information. Nevertheless, the GEOINT process has to be always in concordance with the intelligence process.

1.   Planning and Direction

"Planning and Direction" "…involves the management of the entire intelligence effort, from the identification of the need for data to the final delivery of an intelligence product to a consumer."[53]

In the Planning side of this component of the process, the GEOINT analysts may develop the following tasks:

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[53] Richelson, *The US Intelligence Community*, 4.

Define the problem: Analysts may study the problem presented in order to understand the important parts of the problem to be addressed during the GEOINT process. Hence, GEOINT planners may understand the decision maker intention or mission and they may also study parts of that mission's execution that would require the delivery of GEOINT to be used by the units involved. This study would allow narrowing the problem just in terms of the issues that would require GEOINT. Once the problem has been narrowed, the planners may define it in a way that every analyst involved in the process could understand.

Define GIS criteria: Once the problem is defined, analysts would determine the requirements of information products to be used in the GIS, in order to develop the appropriate GEOINT to solve that problem or to meet the final objective. They may identify which information products they already have in their database, as well as those they may need. They may also establish which entity is responsible for the collection or management of those requirements.

Submit required information products: The required information products are requested of the entity responsible for their collection or management. This step also involves the requests of intelligence to be made to intelligence disciplines other than GEOINT.

Imagery activity

Imagery responsible may receive the requests of information products from the Geospatial and Imagery analysts and it may coordinate with the different imagery collection systems involved to get the information that is not currently in its database.

The <u>Direction</u> side of "Planning and Direction," is interrelated to "evaluation and feedback" which will be explained later in this chapter. In this

component of the process the GEOINT person or persons assigned as managers of a given analysis may control the workflow and synchronize efforts of all the elements and analysts involved. That may be done during every step of the GEOINT process.

2.   Collection[54]

Collection "…involves the gathering, by a variety of means, of raw data…"55 This step in the GEOINT process derives from the requirement information products derived from the previous step. "Not every issue requires the same type of collection support. The requirements depend on the nature of the issue and on the types of collection that are available."56

The collection of information products like digital maps, charts, topographic or hydrographic representations, attribute tables, and statistic data, among others, is done through the governmental or commercial entities dedicated to the production and actualization of those products.

The collection of the imagery is commonly done through means of satellite or airborne "remote sensing" platforms. Remote sensing is defined in the broadest sense as "…the small or large-scale acquisition of information of an object or phenomenon, by the use of either recording or real-time sensing device(s) that is not in physical or intimate contact with the object…"57

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[54] To ensure an effective data management in the GIS within the GEOINT process, it is important that the analysts develop an effective and standardized way to organize data into folders and into databases. Everybody in the GEOINT entity must use the same system of names and organization of the often multiple files to use, so that they understand the shared or public files. It would also allow the analysts to find quickly the files they need to work on when they receive the datasets. The files can be organized by geographical region, type of data (shapefiles, rasters, attribute tables…), or type of attributes, among others. There is no universal system to organize GIS data; however, there are courses of GIS data management that allow for the building of a specific GIS organization system for a given GEOINT organization.

[55] Richelson, *The US Intelligence Community*, 4.

[56] Lowenthal, *Intelligence : From Secrets to Policy*, 59.

[57] Wikipedia contributors, "Remote Sensing," Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/wiki/remote_sensing?oldid=229041120 (accessed date 8/14/2008).

Therefore, satellite platforms are the primary sources of imagery for producing GEOINT. On the other hand, airborne platforms are commonly used at the tactical level; unmanned Aerial Vehicles (UAVs), such as the Global Hawk or Predator, have proved to be an effective source of imagery at that level. They are important for "…their ability to remain airborne for long period of time [which] contributes to persistent surveillance capabilities."[58] These two categories of platforms (satellite and airborne) carry the sensors used to collect data for GEOINT.

> Remote sensors can employ a number of technologies including electronic, optical, electro-optical, chemical, or mechanical systems, either individually or in combination. The information can be recorded or analyzed in either imagery or non-imagery formats using digital or analog means.[59]

In addition, remote sensors "…have evolved from being limited to black-and white visible light photography to producing images using different parts of the electromagnetic spectrum…"[60] such as infrared imagery and multi, hyper, and ultraspectral imagery. Furthermore, other types of GEOINT remote sensors use radar signals to capture images in poor weather and light conditions, as is the case of Synthetic Aperture Radar (SAR).[61]

It is worth mentioning that collection must be limited by the requirements of information products planned in the first step of the GEOINT process. Due to the vast amount of different sensors that now are available, they are commonly overused, resulting in an enormous imagery database that would surpass the exploitation and analytical effort of the GEOINT process. Consequently, most of the imagery collected would never be transformed in usable GEOINT. This would

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[58] United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence : Geospatial Intelligence (GEOINT) Basic Doctrine*, 18-19.

[59] United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence : Geospatial Intelligence (GEOINT) Basic Doctrine*, 18-19.

[60] Richelson, *The US Intelligence Community*, 176.

[61] United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence : Geospatial Intelligence (GEOINT) Basic Doctrine*, 19-21.

result in an immense waste of resources, given the high costs of maintenance and operation of the sensors and their platforms. In addition, "…increased collection also increases the task of finding the truly important intelligence."[62]

Collection may also involve the gathering of intelligence from intelligence disciplines other than GEOINT that was requested in previous steps.

In these terms, once established, the requirements of information products have been requested of the respective sources, the tasks assigned to each of the three elements of GEOINT in the collection step would be:

Geospatial analysis activity

Import information products: The analysts may extract the information products such as digital maps, charts, topographic or hydrographic representations, attribute tables, and statistic data, among others, from their preexistent databases. In addition, the analysts may collect these information products requested in the previous step. It may also involve the gathering of intelligence from intelligence disciplines other than GEOINT.

Build raw dataset: With all the information products at hand, the analysts may first check that these products are the ones that were asked for. Next, the analysts may build a dataset with all the information products, which could be categorized as "geospatial raw dataset" because the information still needs to be processed.

To facilitate the processing task of the next step in the GEOINT process the analysts may update the metadata in every product; this is all the data regarding to that product such as, but not limited to, type of data, source, authors, date of creation and/or updates, projection, coordinates system, datum, scale, and others. In addition, the analyst may organize the data using the previously established data management system (see footnote 54).

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[62] Lowenthal, *Intelligence : From Secrets to Policy*, 54-60.

Collect required information products: Imagery collectors may gather the data required from their own databases, when available, or from the remote sensing devices, when the information is not available in the database or when newer information is needed.

Prepare information products: The data may be studied, prepared, and organized in such a way that favors the process-and-exploitation step. For example, image mosaicing, georreferencing the imagery, capturing metadata in every product, and building datasets divided by regions, data formats, and resolutions (see footnote 54).

Export information products: Once prepared, the data may be delivered to the analysts who requested it.

IMINT activity

Import information products: The analysts may extract information products such as satellite and airborne photos, SAR images, and raster's datasets, among others, from their preexisting databases. In addition, the analysts may collect those information products required, which were already requested of other sources in the previous step. It may also involve the gathering of intelligence from intelligence disciplines other than GEOINT.

Build raw dataset: With all the information products at hand, the analysts may first check that these products are the ones asked for of the sources. Next, the analysts may build a dataset with all the information products, which could be categorized as "IMINT raw dataset" because the information still needs to be processed.

To facilitate the processing task of the next step in the GEOINT process the analysts may update the metadata in every product;, this is all the data regarding that product such as, but not limited to, type of data, collection

platform, sensor used, format, resolution, date of gathering and/or updates, projection, coordinates system, datum, scale, and others. In addition, the analyst may organize the data using the previously established data management system (see footnote 54).

3.   Processing and Exploitation

Processing-and-Exploitation involves the conversion of the "raw datasets" that came into the GIS to a form suitable for the analysis-and-production step.[63] The intelligence collected in the previous step "…does not arrive in ready-to-use form. It must be processed [for example] from digital signals into images or intercepts, and these must then be exploited…"[64] through, for example, photo interpretation if they are images.

One of the most significant tasks in the "processing and exploitation" step is photo-interpretation. This task has been an excellent source of intelligence since WWI "…when aerial photography became a major contributor of battlefield intelligence."[65] Photo interpreters in the IMINT activity analyze the satellite or aerial images gathering a significant amount of information regarding the terrain, objects, and enemy activities. As explained previously, nowadays, the interpreters by means of GIS are able to develop such analytical tasks in an effective way. This is why GEOINT analysts tend to limit their work to just developing photo-interpretation.

However, it is worth noting that using GIS for photo interpretation in the GEOINT process is just using a minimum of these systems' potential. This is because the analysts, by means of GIS, are able to combine the imagery with geospatial data and vector-based maps. That capability, which will be illustrated

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[63] Richelson, *The US Intelligence Community*, 4.

[64] Lowenthal, *Intelligence : From Secrets to Policy*, 60.

[65] Wikipedia contributors, "National Geospatial-Intelligence Agency," Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/wiki/national_geospatial-intelligence_agency?oldid=230555595 (accessed date 8/15/2008).

later in this work, provides the analyst with a powerful tool not only for reinforcing the interpretation task but also for applying complex mathematical models for automatically finding patterns or spatial data that cannot be discovered through means of photo-interpretation. Furthermore, it allows the analysts to work with multiple layers of data and attribute tables that would be almost impossible to get without a computer system. As noted by the NGA:

> While some of the [GEOINT] capabilities may have existed for years, they were not usually combined with other capabilities or were not used routinely due to technology constraints. Advances in commercial technology improve the ability to use and combine capabilities. The integration of these capabilities maximizes the accuracy, effectiveness, and potential of GEOINT products.[66]

The statements in the last paragraphs are the essence of GEOINT, which is "putting together" the elements of Imagery, IMINT, and Geospatial Analysis.

During the development of the tasks given in the "processing and exploitation" step, the analysts may start generating "raw intelligence," which once organized may be analyzed in the "analysis and production" step. Hence, the main tasks to develop in the "processing and exploitation" step given by the GEOINT process model presented in this work include:

Geospatial analysis activity

Put raw dataset into GIS: Once having the raw dataset this may be uploaded into the GIS so it may allow for the processing tasks, which follow this task.

Process data: This refers to preparing all the information uploaded into the GIS in such a way that it can be easily managed and combined during the analysis. Some of the tasks that may be required in this step would be geo-referencing –which is setting points of reference in an image related to

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[66] United States, National Geospatial-Intelligence Agency, *National System for Geospatial Intelligence : Geospatial Intelligence (GEOINT) Basic Doctrine*, 23.

geographic coordinates so that it can be analyzed "spatially" by means of GIS–as well as the synchronization of the geospatial characteristics of the information. Geospatial characteristics refer to coordinates systems, projections, datum, and measurement systems among others. They are often different between files because usually they are acquired from different sources.

Build ready-to-use GIS database: After all of the data that the analysts used has been processed, it has to be organized in a database (see footnote 54).

<p align="center">IMINT activity</p>

Put raw dataset into GIS: The raw dataset may then be uploaded into the GIS so that it may allow the processing tasks, which follow this task.

Process data: This refers to preparing all the information uploaded into the GIS in such a way that it can be easily managed and combined during the analysis. Some of the tasks that may be required in this step would include the combining of different bands of the electromagnetic spectrum in single image[67] or geo-referencing. This is the process of setting points of reference in the imagery related to geographic coordinates in order to allow the combination of the imagery with geospatial data so they could be analyzed "spatially" by means of GIS.

Image interpretation: Analysts may extract substantial data from the images through photo-interpretation and photogrammetry. The former refers to extracting and providing information "…about the nature of the objects in the photographs…" that may provide information about location "…of class of units or objects or an activity of interest [within the imagery]." The photo-interpreters also may look for identifying, whether generally or precisely (depending on the requirements), target types and their descriptions, just to enumerate some of the

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[67] Richelson, *The US Intelligence Community*, 194.

main tasks. "Photogrammetrists are responsible for determining the size and dimensions of objects from overhead photographs, using, along with other data, the shadows cast by objects."[68]

It is worth mentioning that a significant characteristic of the IMINT analysts is that they are especially trained to analyze images and to discover data that the untrained or naked eye cannot. However, advances in GIS now allow interpreters to

> *build multicolored single images out of several pictures taken in different bands of the spectrum, making the patterns more obvious;*

> *restore the shapes of objects by adjusting for the angle of view and lens distortion;*

> *change the amount of contrast between objects and backgrounds;*

> *sharpen out-of-focus images;*

> *restore ground details largely obscured by clouds;*

> *conduct electronic optical subtraction, in which earlier pictures are subtracted from later ones, making unchanged buildings in a scene disappear while new objects, such a missile silos under construction remain;*

> *enhance shadows;*

> *suppress glint.[69]*

Build ready-to-use GIS database: Once all the data that the analysts may use has been processed, it has to be organized in a database (see footnote 54).

4. Analysis and Production

Analysis-and-Production involves the conversion of the "raw intelligence" prepared in the previous step into "finished intelligence." That is because "raw intelligence" "…is often fragmentary and at times contradictory, specialists

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[68] Richelson, *The US Intelligence Community*, 194-195.

[69] Ibid., 194.

[GEOINT analysts] are needed to give it meaning and significance." This step "…includes the integration, evaluation, and analysis of all available data and the preparation of various intelligence products."[70]

It could be argued that in this step the GIS offers the more meaningful support to the GEOINT analysts. That is because GIS analytical software provides them with a powerful tool not only to combine every different data acquired of the factors involved in the problem but also to develop complex mathematical or statistical algorithms that allow the analysts to find some patterns or particular spatial characteristics. To illustrate, one could imagine that when looking for the less costly path of a recon patrol, which has to consider slope, vegetation, bodies of water, and other obstacles in every single part of the area to be covered. In this case, the GIS software, with the appropriate parameters develops the math calculations, called map algebra, and deliver to the analysts the possible paths with their respective value. Developing the same detailed analysis that the GIS software provides without a computer is an almost impossible task for the GEOINT analysts.

Integration of IMINT and geospatial analysis: GEOINT analysts may integrate the "IMINT dataset" and the "geospatial analysis dataset" into the same workspace.

Develop analysis: The GEOINT analysts may use the different functions and tools of the GIS analytical software to find new information or GEOINT. This is often given by "querying the data" whether spatially or by attributes. "Spatial querying," in the most basic extent, refers to the question "what is at this location or near to it?" while "attribute querying" refers to the question "where does this occur?"[71]

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[70] Richelson, *The US Intelligence Community*, 4.

[71] Ian Gregory, "A Place in History: A Guide to using GIS in Historical Research," http://ahds.ac.uk/history/creating/guides/gis/sect42.html (accessed date 8/17/2008).

However, given the diversity of situations that the GEOINT analysts must solve in looking for intelligence, there is not a single way to develop the GEOINT analysis; on the contrary, due to the large number of tools and functions available, developing the analysis is almost limitless. Because of this, GEOINT analysts have to be highly trained in the use of GIS analytical software, which allows them effective exploitation of the product, as well as the ability to test GEOINT results from different perspectives.

Produce GEOINT: The logical result of the GEOINT analysis is the production of GEOINT. This result is given by exhaustive analysis and evaluations. Some evaluation methods will be mentioned in the "evaluation and feedback" step of this process.

Prepare GEOINT for dissemination: Usually the resulted GEOINT may be a map; however, there are many different ways to present it; and GIS gives the analysts the tools for preparing the map for an adequate presentation of the results. This is often given through the preference of the decision makers to whom the analysts may have to disseminate the GEOINT.

5.   Dissemination

Dissemination "…involves the distribution of the finished intelligence to the consumers…" 'Consumers' refers to the decision-makers, commanders, operators, as well as analysts from other intelligence disciplines "…whose needs triggered the process."[72]

It is often said that dissemination is the final step in the intelligence process; however, as has been learned, sometimes getting the final product may take more than one intelligence-cycle, and some other times new information or approaches may come up during the dissemination, forcing the GEOINT to go back to previous steps. In addition, on some occasions the GEOINT has to be incorporated into the whole intelligence mainstream in order to be mixed with

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[72] Richelson, *The US Intelligence Community*, 4.

other intelligence discipline(s). The only thing to keep in mind for the GEOINT analysts is that the GEOINT process is flexible, and it has to be synchronized with the whole intelligence effort.

It is worth noting that some intelligence systems could allow the intelligence analysts to integrate different disciplines and to synchronize their process steps into the intelligence mainstream by giving the analysts the tools to do so "on the fly." Furthermore, GIS now facilitates this integration through compatibility between information-systems-software. Hence, this would be given by the intelligence organizational structure, the problem to solve, the information available, the compatibility between information-systems, and/or the analysts' ability to do so in an effective way among other factors.

Dissemination could be required in many different ways, and that is one of the reasons why a flexible GEOINT process is required. Hence, in the GEOINT-process-model the two most likely situations, which could be presented to the GEOINT analyst, are illustrated as a guideline.

Dissemination (case A); When it is required to incorporate GEOINT to the intelligence mainstream

Incorporate GEOINT into the "collection" step of the intelligence mainstream: The GEOINT analysts may develop this task when the whole intelligence process in the "planning and direction" step requests some GEOINT product of the GEOINT entity. Therefore, once the GEOINT analysts produce that requested information-product they disseminate it to the intelligence-requesters in the collection step of the whole intelligence effort.[73]

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[73] As previously stated, the final product will be a map with data that can be presented by digital means, for example in a display, or printed. The consumer may establish what the best format for receiving the GEOINT. In addition, GIS allows for preparing map projects that can be presented to consumers in a more interactive way, for example displaying the various combinations and parameters that were taken into account during the GEOINT process. This would allow for changes during the dissemination step.

Present GEOINT to the consumers (decision-makers): The GEOINT analysts may develop this task when just GEOINT is required by the decision-makers whether because the situation just requires GEOINT or because GEOINT is the main effort in the intelligence process and that can be complemented with details from other disciplines "on the fly." (See footnote 73)

6.   Evaluation and Feedback

As mentioned previously this is not a step in the process but a component that is more like a quality-control-mechanism, that is developed by the GEOINT analysts and decision-makers involved within the entire process. In addition, it is interrelated to the "direction" side of the "planning and direction" step.

In this regard, in the Joint Intelligence publication 2-0, the Chiefs of Staff established that

> During evaluation and feedback, intelligence personnel at all levels assess how well each of the various types of intelligence operations are being performed. Commanders and operational staff elements must provide feedback. When areas are identified that need improvement, the necessary changes are made. Evaluation and feedback may also serve to refine collection requirements and priorities in phased operations.[74]

Evaluate results in every task: The GEOINT analysts may evaluate every data derived from the different tasks developed during the process. Two such examples of result evaluation obtained from GIS analytical software operations in the GEOINT process include: "sensitivity analysis" and "statistics significance analysis." The former refers to analyze

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[74] United States, Joint Chiefs of Staff, *Joint Intelligence*, 40.

…how a model (numerical, conceptual, or a complex integration of both) responds to changes in its input information. Input information includes data used to calibrate the model, parameters assumed or estimated from the data used to drive the model and the basic assumptions underlying the model.[75]

"Statistics significance analysis" refers to accepting "…the null hypothesis unless there is a very small chance that they would be wrong to reject it." In broad terms, the null hypothesis states that there is no pattern or relationship within the data subject to analyze. Here GEOINT analysts and decision-makers may identify the level of risk they are willing to accept for being wrong. "This degree of risk, often referred to as the confidence level, is expressed as a probability ranging from 0 to 1."[76]

Of course, there are other types of evaluation less "mathematical" such as measuring the quality of a resulting map or image for visualization or comparing imagery with the information in digital maps to verify the precision of the data.

Receive feedback from the decision-makers and other analysts: The GEOINT analyst may always look for feedback from the consumers (decision-makers) because they are the ones whose decisions would be affected by GEOINT. On the other hand, GEOINT analysts involved in the GEOINT process may look for perspectives that are different from other analysts, who are not involved in the analysis. Receiving feedback is always required during the GEOINT process; however, one could argue that during and after the dissemination, feedback from the consumers is remarkably important. This is because the whole GEOINT effort is providing the consumers with the adequate intelligence products for the effective development of their activities.

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[75] D. J. Maguire, Michael Batty and Michael F. Goodchild, eds., *GIS, Spatial Analysis, and Modeling* (Redlands, California: ESRI Press, 2005), 74.

[76] Andy Mitchell, *The ESRI Guide to GIS Analysis; Spatial Measurements and Statistics*, Vol. 2nd vol (Redlands, CA: ESRI Press, 2005), 11-12.

Determine what can be improved: Once the results from the evaluations and/or different feedback have been received, the analysts may determine what can be improved and take the required actions for resolving that situation.

Go back to previous steps if necessary: When improving the results or tasks in the GEOINT process the analysts may consider going back to previous steps, if necessary, to improve the process.

In executing the GEOINT process, analysts may base their effectiveness on synchronizing the GEOINT components efforts as well as on synchronizing the entire GEOINT effort with the intelligence mainstream. In addition, all the way around the GEOINT process the analysts may have the specific consumer's requirements in mind and in order for the analyst to understand what exactly the consumer wants, an open interaction may occur by means of "evaluation and feedback" during the GEOINT process.

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III. GIS AND PRACTICAL APPLICATIONS FOR THE MEXICAN NAVY

> GIS [Geographic Information Systems] will become as much a part of our lives as computers are today.

> Roger Tomlinson in: "Thinking about GIS

A. GIS AND ARCGIS TOOLSETS

Currently, geospatial technology has added several software applications in the information systems' field. These applications are widely used by many fields as a tool for developing geospatial analysis. Additionally, within the intelligence arena, they provide the GEOINT analysts with powerful tools with which to develop their everyday tasks.

Therefore, GIS applications provide a platform in order to access, transform, transfer, overlay, and display the information during the analysis. Furthermore, geospatial analysis and/or GEOINT, supported by analytical software, provide automatic analysis capabilities to the decision-makers "because of the huge capacity of today's computers, the amount of information they hold is almost infinite. . . . A GIS allows for a dialogue between the map and the map user . . . This is called interactive mapping, and this is the cornerstone of this latest revolution in cartography… The application of GIS is limitless."[77]

In its conception, GIS was originally designed to process remote sensed data from satellite and aerial surveys. As such, these systems may have been used effectively as image-processing-software as well as for developing visual analysis to exploit the images by extracting from them high value geospatial information or intelligence. As time and capability increased, some GIS "…have developed into much more sophisticated and complete GIS tools (e.g. Clark Labs Idrisi software; MicroImage's TNTMips product set; Leica's ERDAS Imagine…)"

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[77] Holt-Jensen, *Geography, History and Concepts : A Student's Guide*, 228.

but they have often focused more on image handling and their processing. "Whatever their origins, a central purpose of such tools has been the capture, manipulation and interpretation of image data, rather than spatial analysis per se, although the latter inevitably follows from the former."[78]

On the other hand, there are software applications that have developed a wide range of geospatial analytical tools, as in the case of ArcGIS, and they have combined image processing with geospatial analytical tools resulting in a very effective support for entities that need both capabilities. This can be aptly illustrated in the case of GEOINT entities and military institutions, which always require complex tasks that require a combination of tools. Additionally, it is worth mentioning that many of the tools that will be discussed in this chapter were developed by the Environmental Systems Research Institute (ESRI) and are available in ArcGIS software.

As we learned in Chapter II, the intelligence community, in the past few years, has been primarily relying on IMINT to produce intelligence derived from imagery visualization and analysis. However, as GIS capabilities evolved, so did the capabilities of intelligence in the field. Hence, advances in GIS provided the imagery processors and IMINT analysts with the ability not only for the integration of both activities but also for complementing them with the activity of geospatial analysis.

For example, in the case of the U.S., despite the fact that since its creation in 1996 the National Imagery and Mapping agency (NIMA) absorbed the Defense Mapping Agency (DMA), among other entities, it was not until 2003 that the U.S."…recognized the emergence of geospatial information as an intelligence source in its own right…" Consequently, the NGA was created and the GEOINT concept adopted.[79]

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[78] Michael John De Smith, Michael F. Goodchild and Paul Longley, *Geospatial Analysis: A Comprehensive Guide to Principles, Techniques and Software Tools*, 2nd ed. (Leicester: Matador, 2007), 6.

[79] National Research Council (U.S.) and others, *Priorities for GEOINT Research at the National Geospatial-Intelligence Agency*, 9.

So then, geospatial operations that can be developed by modern GIS, some are vector-based and some others are raster-based. Vector-based GIS involves

> …operations such a map overlay (combining two or more maps or map layers according to predefined rules) [Figure 12], simple buffering (identifying regions of a map within a specific distance of one or more features, such as towns, roads or rivers) [Figure 13] and similar basic operations.[80]
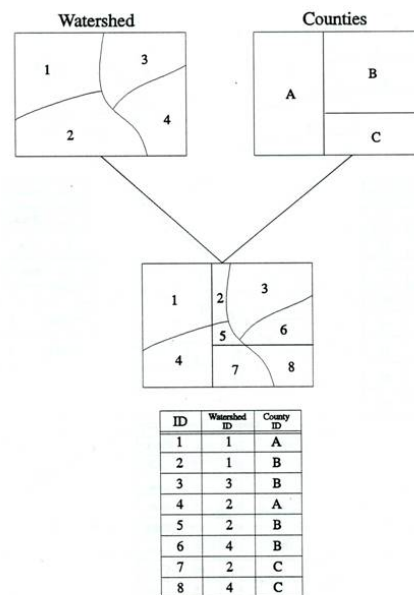
Figure 12.   Overlaying (polygon on polygon) between vector-based-maps. The combination results in a new vector map.[81]

Vector-based-maps include point feature class, which refers to locations or events represented by georeferenced points; line feature class, which refers to flows, roads, divisions, or other linear aspects represented by georeferenced lines; and polylline, which is a combination of the two.

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[80] De Smith, Goodchild and Longley, *Geospatial Analysis : A Comprehensive Guide to Principles, Techniques and Software Tools*, 3.

[81] Retrieved from: http://www.geo.wvu.edu/~elmes/geog350/Images/unit%2014%20Dia%206.jpg , (accessed date 8/21/2008).
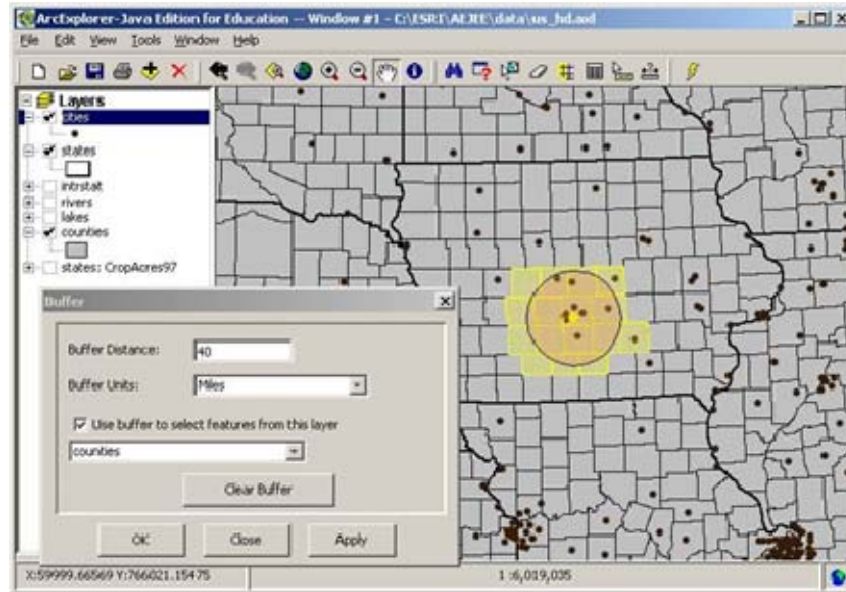
Figure 13.   40 mile buffer from a position (yellow point) in Des Moines, Iowa; the purpose was to find which counties are embraced by that distance. GIS automatically selected the counties covered by the buffer.[82]

On the other hand, raster-based GIS (Figure 14), which is extensively employed for environmental and remote sensing purposes, involves

> …a range of actions applied to the grid cells [pixels] of one or more maps (or images) often involving filtering and/or algebraic operations (map algebra). These techniques involve processing one or more raster layers according to simple rules resulting in a new map layer…[83][Figure 15]

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[82] Retrieved from http://blogs.esri.com/Info/blogs/gisedcom/archive/2007/09/16/cf.aspx , (accessed date 8/21/2008).

[83] De Smith, Goodchild and Longley, *Geospatial Analysis : A Comprehensive Guide to Principles, Techniques and Software Tools*, 3.
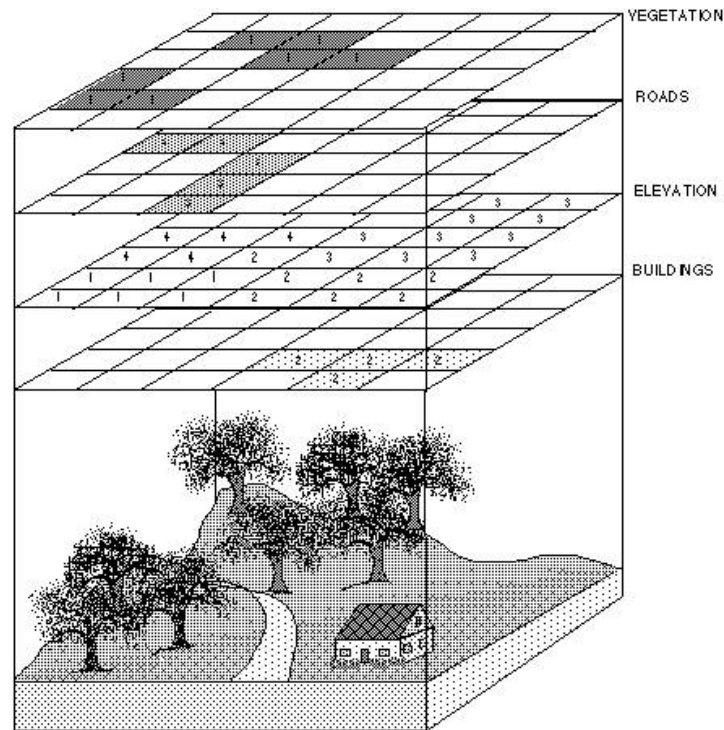
Figure 14.   Diagrammatic model showing how raster datasets represent real world features.[84]
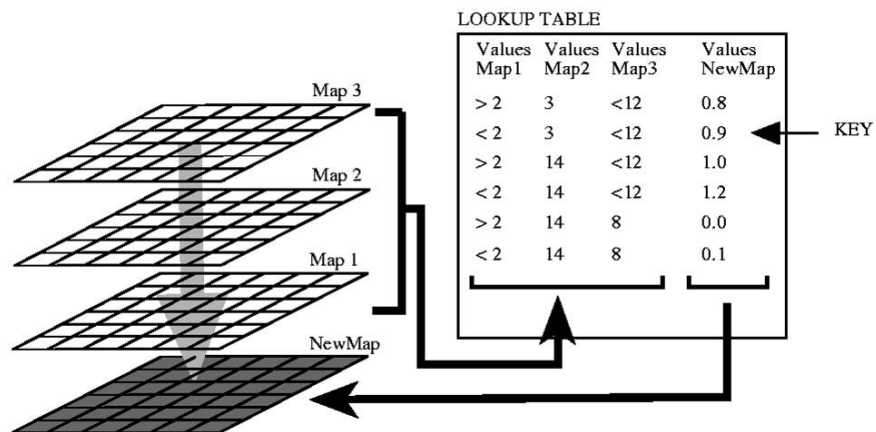
Figure 15.   Properties on raster "NewMap" resulted from the combination of attributes (values) in the cells of rasters (maps) 1, 2, and 3.[85]

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[84] Retrieved from:
http://gis.washington.edu/cfr250/lessons/introduction_gis/spatial_data_model.html , (accessed date 8/21/2008).

[85] Retrieved from: http://pcraster.geo.uu.nl/documentation/pcrman/x120.htm , (accessed date 8/21/2008).

In addition, GIS includes a large amount of descriptive, explanatory, exploratory, and predictive statistical methods designed for spatial and temporal data; the application of these methods is commonly referred to "geostatistics" or spatial statistics.[86] Furthermore, GIS not only involves 2D mapping operations and/or geostatistics but also includes

> …other very important areas to be considered. These include: surface analysis –in particular analysing [sic] the properties of physical surfaces, such as gradient, aspect and visibility, and analysing [sic] surface-like data "fields"; network analysis – examining the properties of natural and man-made networks in order to understand the behaviour [sic] of flows within and around such networks; and location analysis.[87]

3D analysis and visualization is another important capability of GIS. It allows the creation of 3D images, maps, diagrams, charts as well as their associated datasets. It also provides for the capability of manipulating those 3D environments in such a way that provide the analysts with a very realistic presentation of the geographical environment.[88] 3D analysis develops its operations over TIN (Triangulated Irregular Network) data or TIN-based-maps, where TIN is described as:

> A vector data structure that partitions geographic space into contiguous, nonoverlapping [sic] triangles. The vertices of each triangle are sample data points with x-, y-, and z-values. These sample points are connected by lines to form Delaunay triangles. TINs are used to store and display surface models.[89] (Figure 16)

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[86] De Smith, Goodchild and Longley, *Geospatial Analysis : A Comprehensive Guide to Principles, Techniques and Software Tools*, 3.

[87] Ibid., 3.

[88] De Smith, Goodchild and Longley, *Geospatial Analysis : A Comprehensive Guide to Principles, Techniques and Software Tools*, 4.

[89] ESRI, "GIS Dictionary - ESRI Support; Triangulated Irregular Network (TIN)," http://support.esri.com/index.cfm?fa=knowledgebase.gisDictionary.search&searchTerm=TIN (accessed date 8/21/2008).
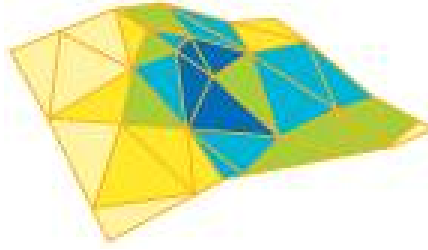
Figure 16.   Triangulated Irregular Network (TIN) data[90]

While GIS contains a large number of tools and capabilities in this work, only the most important are discussed in this thesis, in particular those that can be applied in the GEOINT and military fields. Moreover, because ArcGIS has already gained wide acceptance in the intelligence and military communities as well as the Mexican Navy, its use is emphasized here. Therefore, some of the ArcGIS tools are presented in the following paragraphs.

1.   Spatial Analyst Tools

From the three GIS data structures described earlier (vector, raster, and TIN), "…the raster data structure provides the most comprehensive modeling environment for spatial analysis." As seen earlier, raster data is a cell-based system and "…Each cell represents a certain specific portion of the earth, such as a square kilometer, hectare, or square meter." In addition, every cell includes a value based on its attributes (found in its attribute table). Those attributes could be elevation, vegetation density, soil, and so on (see Figure 14 on p. 55). That raster data quality allows ArcGIS to allocate considerable amounts of data in a single cell, providing greater diversity for both discrete and continuous data in spatial analysis. [91] This structure is different from the one of vector data that

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[90] Retrieved from:
http://support.esri.com/index.cfm?fa=knowledgebase.gisDictionary.search&searchTerm=TIN ,
(accessed date 21/8/2008).

[91] ESRI, "ArcGIS Desktop Help 9.2 - an Overview of the Spatial Analyst Toolbox,"
http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=An_overview_of_the_Spatial_A
nalyst_toolbox (accessed date 8/21/2008).

counts on uniform structure. However, ArcGIS provides the flexibility of combining different data structures or even converting them according to the requirements of the analyst. Such tools include:

a. *Spatial analyst / Conditional tools:* These tools allow the analyst to control the output values by imposing conditions to the input values.[92] Conditional tools can develop complex statements; however, in this case a very basic example is illustrated in Figure 17.
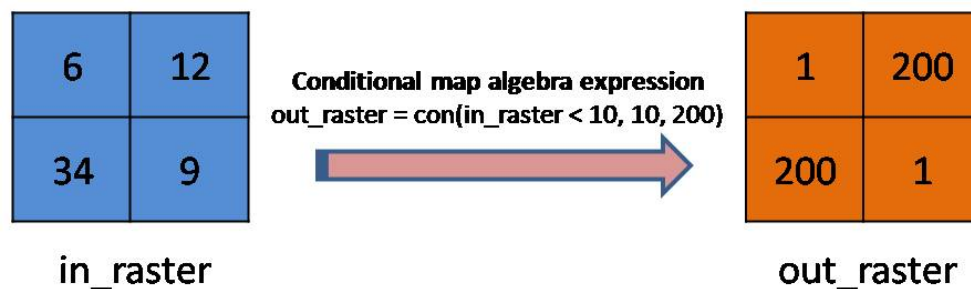
Figure 17.   Basic example of a conditional operation in spatial analysis

The map algebra expression in Figure 17 means that the cells in the output raster, which will be named "out_raster," will have a value of 10 if they have a value of <10 in the input raster, named "in_raster," otherwise the cell value in the out_raster will be 200.

b. *Spatial analyst / Density tools*: When developing density analysis by means of ArcGIS' density tools the analyst is able to know the concentration of a given phenomena or attribute in an area, cell, or radius, which are represented as density surfaces. "Density surfaces show where point or line features are concentrated" within a

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[92] IESRI, "ArcGIS Desktop Help 9.2 - an Overview of the Spatial Analyst Toolbox," http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=An_overview_of_the_Spatial_Analyst_toolbox (accessed date 8/21/2008).

neighborhood or predetermined area. There are three types of methods to calculate density by means of ArcGIS and they are point density, line density, and Kernel density that will be explained below.[93]

1) Spatial Analyst / Density / Point Density: This tool "Calculates a magnitude per unit area from point features that fall within a neighborhood around each cell."[94] The analyst defines the neighborhood's shape, which could be a circle, cell, annulus (doughnut), rectangle, or wedge, as well as its dimension. For example, the analyst might map the density of attempted street robberies occurring over a year in neighborhoods that constitute map cells (represented by rectangles in the figure), Figure 18.

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93 ESRI, "ArcGIS Desktop Help 9.3 - an Overview of the Density Tools," http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=An_overview_of_the_Density_tools (accessed date 11/5/2008).

94 Ibid.
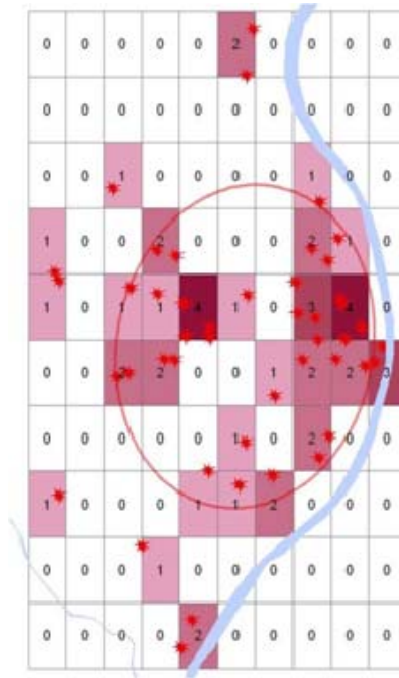
Figure 18.   Point Density Map. Attempted Street Robberies in a 10 x 10 Grid[95]

2) <u>Spatial Analyst / Density / Line Density</u>: This tool "…Calculates a magnitude per unit area from polyline features that fall within a radius around each cell. Density is measured in length of lines per unit area."[96] A radius established by the analyst defines the neighborhood around each cell from what the concentration of lines is measured in this kind of density map (Figure 19). A good example of how this tool can be used by the Mexican Navy in the practice of counter-drugs operations is illustrated later in this work (p. 90).

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[95] Retrieved from http://openglobe.googlepages.com/geog586_geographic_information_analysis22 , (accessed date 11/5/2008).

[96] ESRI, "ArcGIS Desktop Help 9.3 - an Overview of the Density Tools," http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=An_overview_of_the_Density_tools (accessed date 11/5/2008).
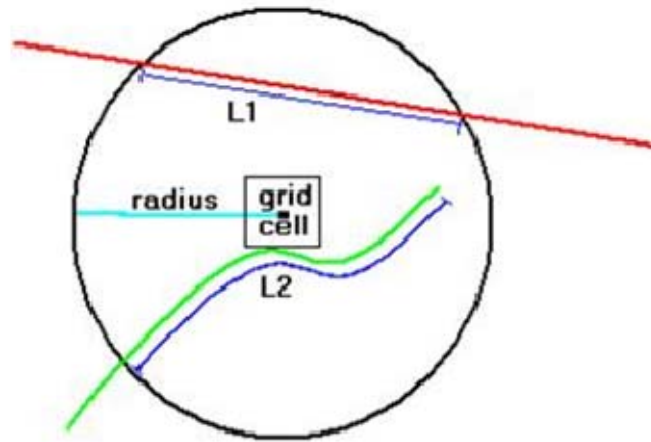
Figure 19.   Raster cell using a circular neighborhood to calculate line density[97]

> 3) Spatial Analyst / Density / Kernel Density: This tool

…calculates the density of features in a neighborhood around those features. It can be calculated for both point and line features. . . . . . Conceptually, a smooth, curved surface is fitted over each line in kernel density for line features. Its value is greatest when it is on the line and diminishes as it moves away from the line, reaching zero at the search radius distance from the line,[98] Figure 20.

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[97] Retrieved from http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Density_calculations , (accessed date 11/5/2008).

[98] ESRI, "ArcGIS Desktop Help 9.3 - how Kernel Density Works," http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?topicname=how_kernel_density_works (accessed date 11/5/2008).
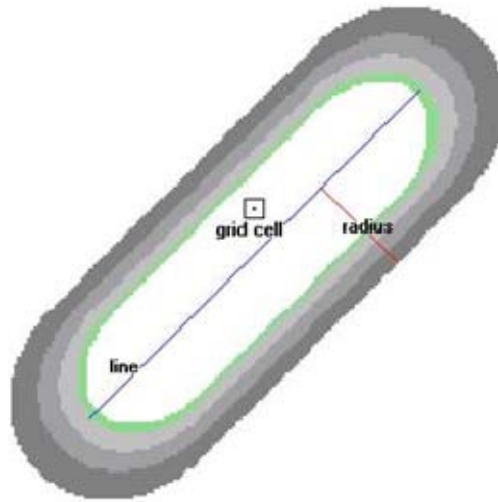
Figure 20. Line with calculation of Kernel density and the grid of reference[99]

c. *Spatial analyst / Distance tools*: Distance analysis can be performed in two main ways whether by calculating the "Euclidean distance" or the "cost distance":

The Euclidean distance functions measure straight-line distance from each cell to the closest source (the source identifies the objects of interest, such as wells, roads, or a school). The cost distance functions (or cost weighted distance) modify Euclidean distance by equating distance as a cost factor, which is the cost to travel through any given cell. For example, it may be shorter to climb over the mountain to the destination, but it is faster to walk around it.[100]

d. *Spatial analyst / Local tools*: Local analysis allows one to "…combine the input rasters, calculate a statistic, or evaluate a criteria [sic] for each cell in an output raster based on the values of each cell from

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[99] Retrieved from
http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Density_calculations ,
(accessed date 11/5/2008).

[100] ESRI, *ArcGIS Desktop Help 9.2 - an Overview of the Spatial Analyst Toolbox*.

multiple input rasters. For example, [one] can find the mean precipitation for a ten-year period or find how many years the precipitation exceeded 0.5 meters."[101]

e. *Spatial Analyst / Map Algebra tools*: "Map Algebra is the analysis language for ArcGIS Spatial Analyst. It is a simple syntax similar to algebraic syntax. For example, to create a slope map from an elevation surface, use the following command: outslope–slope (elevation)."[102] This is a widely used tool in spatial analysis and it offers flexibility in developing from single to multiple complex raster operations. An example of a map algebra expression is presented in Figure 17 on p. 58.

f. *Spatial Analyst / Overlay tools:* This set of tools allows the analyst to establish specific criteria in a query in order to identify the suitability of each cell allocation. The specific "…criteria can be relative costs, preferences, or risks." When looking for "suitability," overlay tools develop combinations of criteria to answer questions such as: Where is the safest insertion zone for my airborne forces? What is the less exhausting route for the ground forces? Moreover, what is the fastest route for evacuating a strategic facility? In this toolset the "weighted overlay tool" allows the analyst to "…easily reclassify [the] data, weight the datasets, and combine them to create a suitability map."[103] Figure 21

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[101] ESRI, *ArcGIS Desktop Help 9.2 - an Overview of the Spatial Analyst Toolbox.*
[102] Ibid.
[103] Ibid.
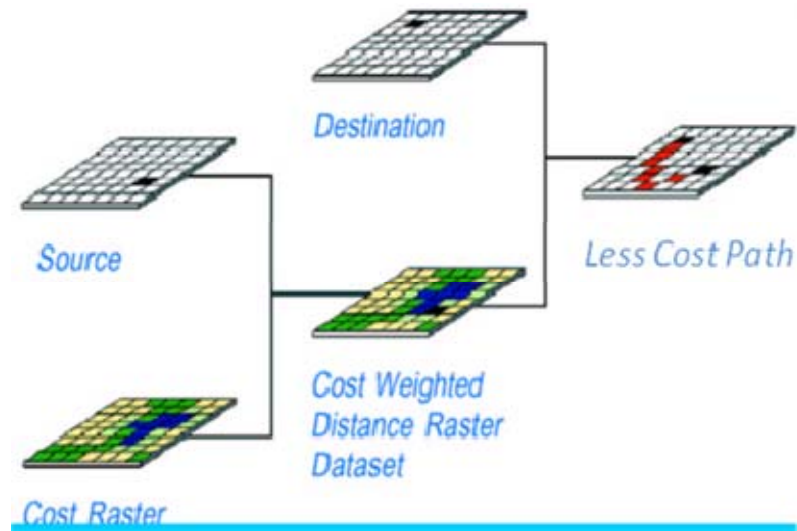
**Figure 21.   Representation of an overlaying suitability operation that
looks for the less cost path given by the input criteria**

    g. *Spatial Analyst / Surface:* This toolset is quite useful for analysts who
are providing terrain information to the ground forces. It produces
patterns, such as slopes, contours, steepest downslope direction
(aspect), viewshed, and shaded relief (hillshade), which would not be
readily apparent when observing the original image or map.[104] The
following paragraphs will briefly describe some of the tools that provide
these patterns:

    1) Spatial Analyst / Surface / Aspect: This tool identifies patterns given
by the "…downslope direction of the maximum rate of change in
value from each cell to its neighbors. Aspect can be thought of as
the slope direction. The values of the output raster will be the
compass direction of the aspect."[105] Figure 22

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104 ESRI, *ArcGIS Desktop Help 9.2 - an Overview of the Spatial Analyst Toolbox.*
105 Ibid.
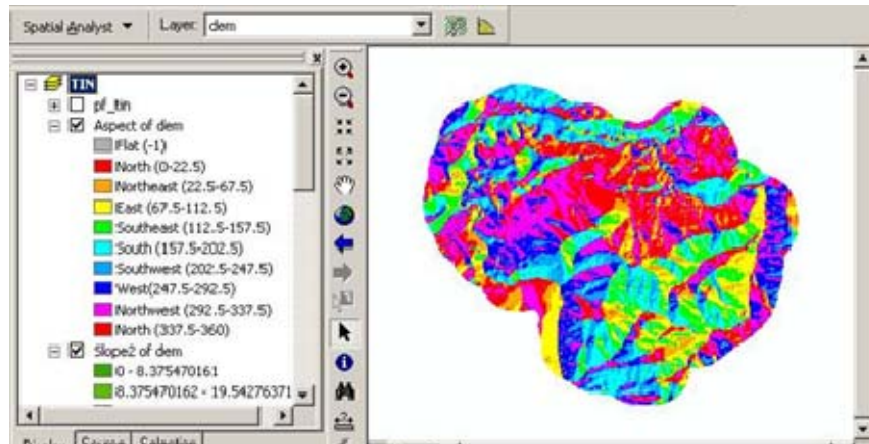
Figure 22.   Map showing the "aspect" pattern with the interpretation of direction given by the different colors showing in the table of contents (left side of the display)[106]

2) <u>Spatial Analyst / Surface / Slope</u>: This tool identifies maximum changes of "z" values (heights/elevations) from each cell in the raster.[107] Figure 23
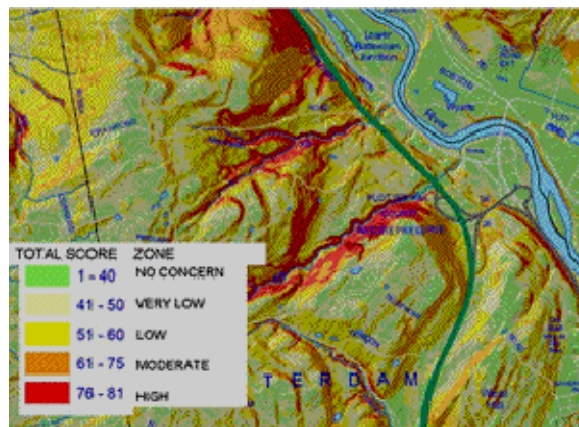
Figure 23.   Map edited showing the "slope" pattern with the interpretation of steepness given by the different colors[108]

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[106] Retrieved from: http://gis.washington.edu/esrm250/lessons/3d/exercise/index.html , (accessed date 8/26/2008).

[107] ESRI, *ArcGIS Desktop Help 9.2 - an Overview of the Spatial Analyst Toolbox*.

[108] Retrieved from: http://www.nysgis.state.ny.us/outreach/gist/win08.html , (accessed date 8/26/2008).

3) <u>Spatial Analyst / Surface / Contour</u>: This tool allows analysts to find areas with the same value such as elevations, temperatures, precipitation, or atmospheric pressure. "The distribution of the polylines shows how values change across a surface. Where there is little change in a value, the polylines are spaced farther apart. Where the values rise or fall rapidly, the polylines are closer together."[109] Figure 24
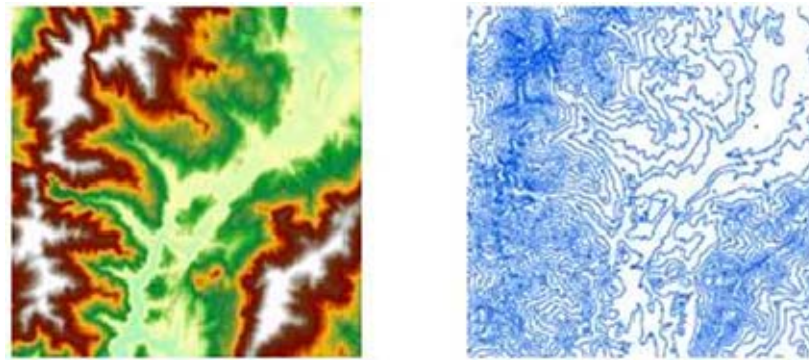
Figure 24.   Contour layer (right) obtained from a Digital Elevation Model (left) through the "contour" tool[110]

4) <u>Spatial Analyst / Surface / Hillshade</u>: The analyst can create a

…hillshade for both graphical and analytical purposes. Graphically, a hillshade can provide an attractive and realistic backdrop, showing how other layers are distributed in relation to the terrain relief. From an analytical point of view, one can analyze how the landscape is illuminated at various times of the day by lowering and raising the sun angle.[111]

[109] ESRI, *ArcGIS Desktop Help 9.2 - an Overview of the Spatial Analyst Toolbox*.

[110] Retrieved from: http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Creating_contours_in_Spatial_Analyst , (accessed date 8/26/2008).

[111] ESRI, *ArcGIS Desktop Help 9.2 - an Overview of the Spatial Analyst Toolbox*.

This is a very functional tool for military purposes because it allows the analyst to find shaded allocations to conceal forces from the enemy sight, Figure 25.
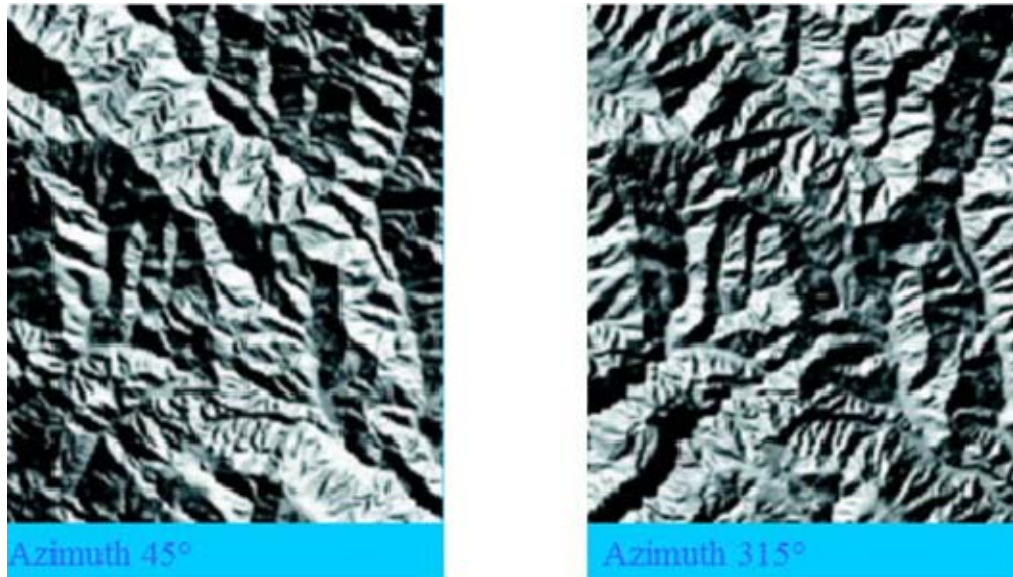
Figure 25.   Hillshade of the same landscape showing different illumination given by different positions of the sun during the day[112]

5) Spatial Analyst / Surface / Viewshed[113]: This is another useful tool for the military analyst; it provides information regarding the visibility field of one's own forces from enemy positions that can help on determining the best allocation for observation points, among other capabilities, Figure 26.

Viewshed identifies the cells in an input raster that can be seen from one or more observation points or lines. Each cell in the output raster receives a value that indicates how many observer points can be seen from each location. If there is only one observer point, each cell that can see that observer point is given a value of one.

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[112] Retrieved from: http://www.urbanecology.washington.edu/GIS_Tutorial/Lecture%206-7.htm , (accessed date 8/26/2008).

[113] Viewshed is also referred as "visibility" or "visibility analysis." In addition, several GIS analytical software refers to "radiate" rather than viewshed.

All cells that cannot see the observer point are given a value of zero. The observer points feature class can contain points or lines. The nodes and vertices of lines will be used as observation points.[114]
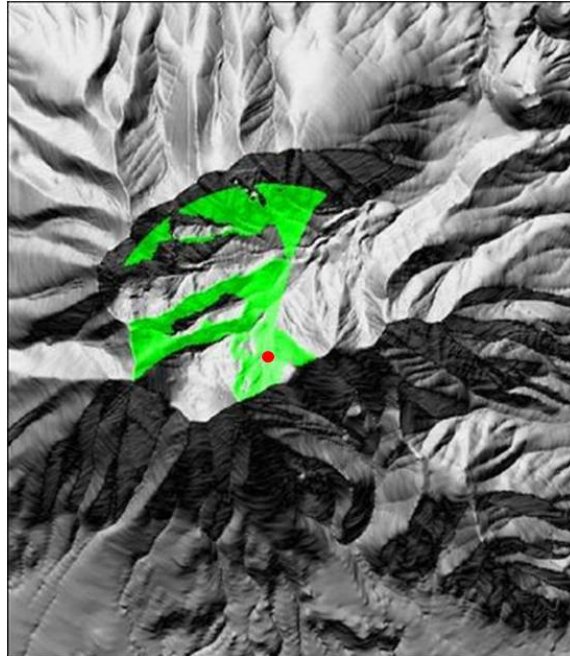
Figure 26.   Viewshed analysis in a hillshade; green areas can be seen from the observation (red) point.[115]

[Figure 27] …graphically depicts how a viewshed is performed. The observation point is on the mountain top to the left (at OF1 in the image). The direction of the viewshed is within the cone looking to the right. One can control how much to offset the observation point (for example, the height of the tower), the direction in which to look, and how high and low to look from the horizon.[116]

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[114] ESRI, "ArcGIS Desktop Help 9.2 - Performing a Viewshed Analysis," http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Performing_a_viewshed_analysis (accessed date 08/16/2008).

[115] Retrieved from: http://freegeographytools.com/2007/i-can-see-my-house-from-here-line-of-sight-and-viewsheds-in-microdem , (accessed date 8/26/2008).

[116] ESRI, *ArcGIS Desktop Help 9.2 - an Overview of the Spatial Analyst Toolbox.*
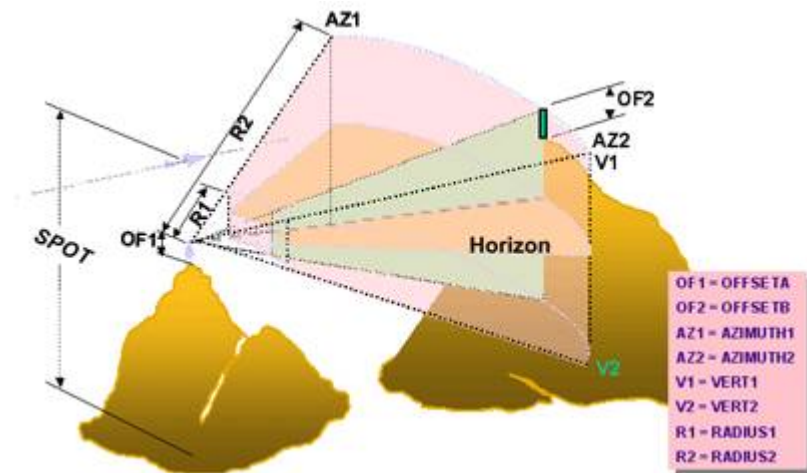
Figure 27.   Illustration of the different viewshed's characteristics that can be controlled by the analyst in ArcGIS[117]

6) <u>Spatial Analyst / Surface / Observer Points</u>: This operation is based on the same principles as the viewshed analysis but the Observer Points tool "identifies exactly which observer points are visible from each raster surface location."[118]

2.   Spatial Statistics Tools

In some cases, the GEOINT analyst will just identify features in a map and symbolize them, resulting in a map full of layers with different symbols. Conclusions can be drawn, based on the combination of different layers and visualization. In some cases, this would be enough for the GEOINT consumers; however, how the analysts"…classify and symbolize features and values on a map can obscure the information, and humans see patterns and relationships everywhere–even sometimes when they don't [sic] really exist."[119] In other

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[117] Retrieved from: http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=Performing_a_viewshed_analysis , (accessed date 8/26/2008).

[118] ESRI, *ArcGIS Desktop Help 9.2 - an Overview of the Spatial Analyst Toolbox*.

[119] Mitchell, *The ESRI Guide to GIS Analysis; Spatial Measurements and Statistics*, 2.

situations, the amount of information is so large and the data so complex that it is almost impossible for the analyst to obtain patterns from it.

Fortunately, in that regard, GIS now includes sophisticated statistical tools based on mathematical operations. These operations can be either very basic formulas or complex mathematical algorithms employed to describe and summarize large quantity of data, which allow analysts to discover patterns that are useful in geospatial analysis. As noted by Mitchell, "Space is a fundamental component of these statistics. That's [sic] what sets them apart from traditional statistics used to analyze aspatial data (tables of data values)."[120]

Among the benefits of working with spatial statistics, we can find that the analyst can easily "…compare sets of features or track changes over time without having to guess." In addition, spatial statistics allow the analyst to derive information for a sample of features in a given area, as well as "…[to] predict unknown values from known sample values."[121]

Using spatial statistics is a relative new discipline, whether because many people see "statistics" as a complicated field or because the older GIS systems did not have that capability. On the other hand, most geospatial analysts have been unaware of the spatial statistics tools and how they can be applied in their field of interest.[122]

ArcGIS analytical software offers a wide range of operations within the spatial statistics toolbox. It

> …contains statistical tools for analyzing the distribution of geographic features: finding the geographic center, identifying statistically significant spatial clusters (hot spots) or outliers, assessing overall patterns of clustering or dispersion, and so on.

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[120] Mitchell, *The ESRI Guide to GIS Analysis; Spatial Measurements and Statistics*, 2.

[121] Ibid., 3.

[122] Ibid., 3.

Spatial statistics differ from traditional statistics in that space and spatial relationships are an integral and implicit component of their mathematics.[123]

Figure 28 is a self-explanatory illustration about the combination of capabilities provided by spatial statistics by means of GIS analytical software.
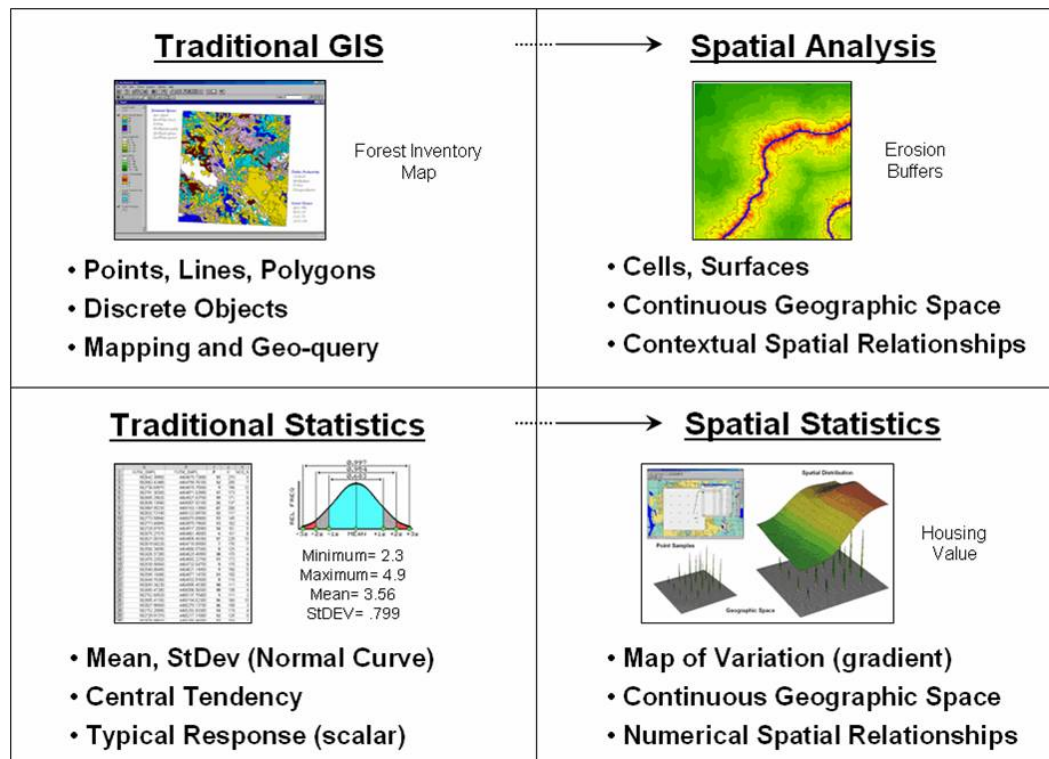
Figure 28.   GIS allows the combination of Spatial Analysis and Statistics to provide the analyst with the capability to develop Spatial Statistics[124]

1). Spatial Statistics / Measuring Geographic Distributions / Central Feature: This tool identifies the central feature from several that are dispersed in a geographic area. This tool is useful because the sole use of visual analysis can mislead the analyst. For example, in

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123 ESRI, "ArcGIS Desktop Help 9.2 - an Overview of the Spatial Statistics Toolbox," http://webhelp.esri.com/arcgisdesktop/9.2/index.cfm?TopicName=An_overview_of_the_Spatial_Statistics_toolbox (accessed date 8/26/2008).

124 Retrieved from: http://www.innovativegis.com/basis/Papers/Other/ASPRSchapter/ , (accessed date 8/26/2008).

looking for a place to establish a police station the analyst may find the central feature in a map that shows the points of crimes in a period by means of ArcGIS, Figure 29.
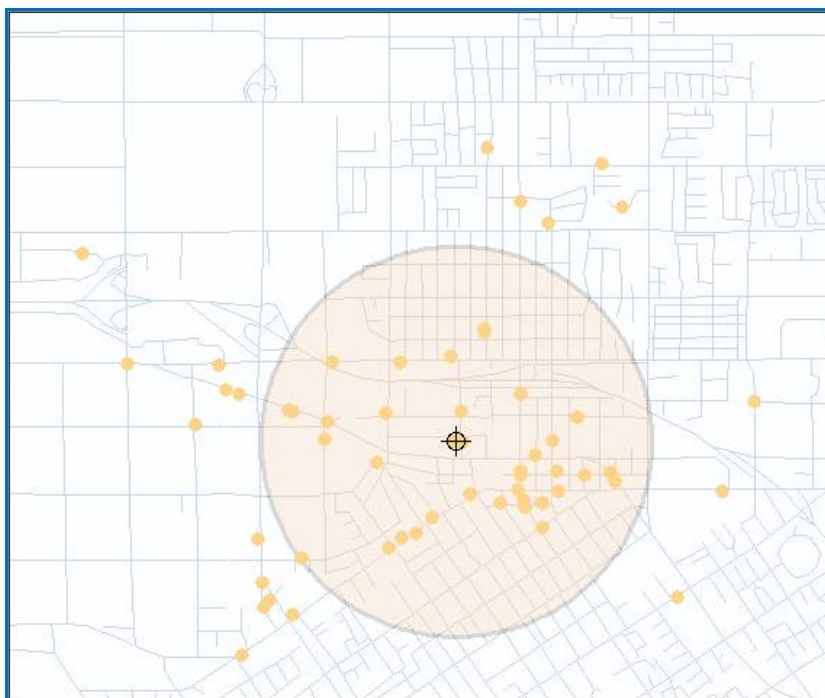
Figure 29.   Burglaries and their central feature in Lincoln, Nebraska[125]

2) Spatial Statistics / Mapping Clusters / Hot Spot Analysis: This tool calculates the

…statistic for each feature in a dataset. The resultant Z score reports where features with either high or low values cluster spatially. This tool works by looking at each feature within the context of neighboring features. A feature with a high value is interesting, but may not be a statistically significant hot spot. To be a statistically significant hot spot, a feature will have a high value and be surrounded by other features with high values as well. The

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[125] Retrieved from http://www.esri.com/news/arcuser/0405/ss_crimestats1of2.html , (accessed date 11/5/2008).

local sum for a feature and its neighbors is compared proportionally to the sum of all features; when the local sum is very different from the expected local sum, and that difference is too large to be the result of random chance, a statistically significant Z score results, Figure 30.[126]
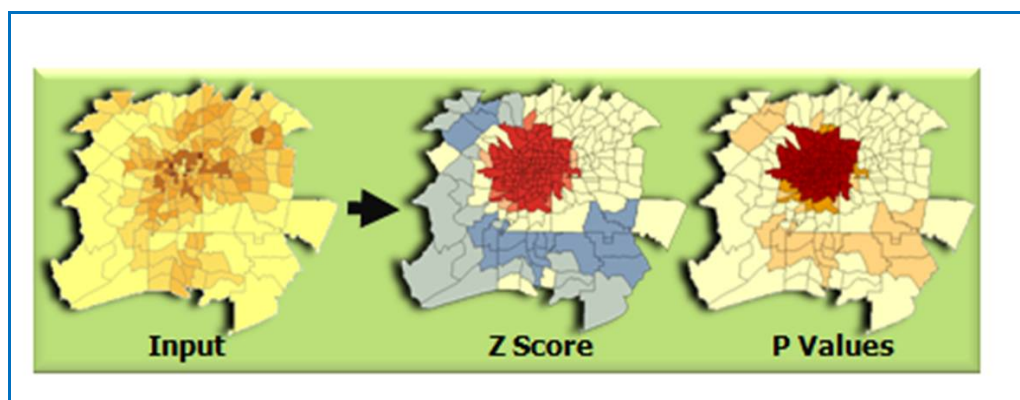
Figure 30.   Illustration of the Z and P values in a Hot Spot Analysis[127]

The Hot Spot tool is particularly important for security forces when they attempt to identify patterns of crime or clusters to focus on in a geographic area. In this case, the host spots would be areas with high crime intensity, Figure 31. By means of this tool, the analyst is able to identify

…spatial clusters of statistically significant high or low attribute values. Given a set of weighted data points, such as the number of crimes per census block, and operating under the expectation that data values are randomly distributed across the study area, this tool delineates clusters of census blocks with higher than expected crime incidents.[128]

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[126] ESRI, "ArcGIS Desktop Help 9.3 - how Hot Spot Analysis: Getis-Ord Gi* (Spatial Statistics) Works," http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=How Hot Spot Analysis: Getis-Ord Gi* (Spatial Statistics) works (accessed date 11/5/2008).

[127] Retrieved from http://webhelp.esri.com/arcgisdesktop/9.3/index.cfm?TopicName=Hot_Spot_Analysis_(Getis-Ord_Gi*)_(Spatial_Statistics) , (accessed date 11/5/2008).

[128] ESRI, "1-Extend Crime Analysis with ArcGIS Spatial Statistics Tools," http://www.esri.com/news/arcuser/0405/ss_crimestats1of2.html (accessed date 11/5/2008).
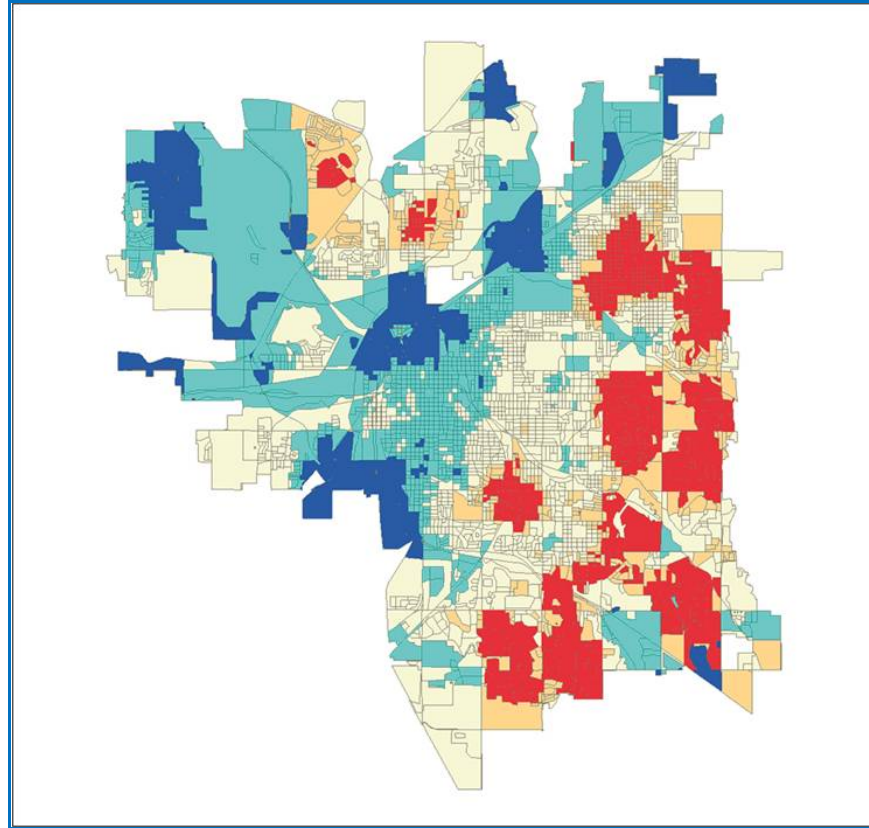
**Figure 31.   Hot spot analysis using vandalism data that was normalized
with data from all crime incidents for Lincoln, Nebraska. Areas with a high
incidence of vandalism are shown in bright red and low vandalism areas
are shown in dark blue[129]**

3.   Tracking Analyst Tools

The Tracking Analyst toolset provides the analyst the ability to incorporate the fourth dimension (Time) to the data. As a result, GIS present the data in such a way that enables sophisticated visualization of the phenomenon to be analyzed. This toolset, as in the case of almost all the toolsets in ArcGIS, can be combined with other GIS

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[129] Retrieved from http://www.esri.com/news/arcuser/0405/ss_crimestats1of2.html ,
(accessed date 11/5/2008).

…extensions to create powerful applications for transportation, emergency response, military, and a host of other areas. The extension allows users to view and analyze existing temporal data, which can be set up with future time windows (for mission planning) or past time windows (for historical data analysis).[130]

"Military Overlay Editor" (MOLE), is one of important extensions that can be used in combination with tracking analyst tools. MOLE "…is a symbol generator and editor for military applications."[131] Figure 32

Figure 32.   Map showing military units in movement with buffers established according to the range of some of their detection devices[132]

A Tracking analyst is also useful for plotting and prediction of trajectory or meteorological phenomena as in the case of hurricanes, Figure 33. This

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[130] ESRI, "ESRI News -- ArcNews Summer 2002 Issue -- Introducing ArcGIS Tracking Analyst and ArcIMS Tracking Server," http://www.esri.com/news/arcnews/summer02articles/introducing-arcgis-ta.html (accessed date 8/26/2008).

[131] Ibid.

[132] Retrieved from: http://www.esri.com/industries/defense/business/military_ops.html , (accessed date 8/26/2008).

capability allows the decision makers to take preventive measures in the potential affected areas, as well as to establish patterns in the study of the development of this kind of phenomena.
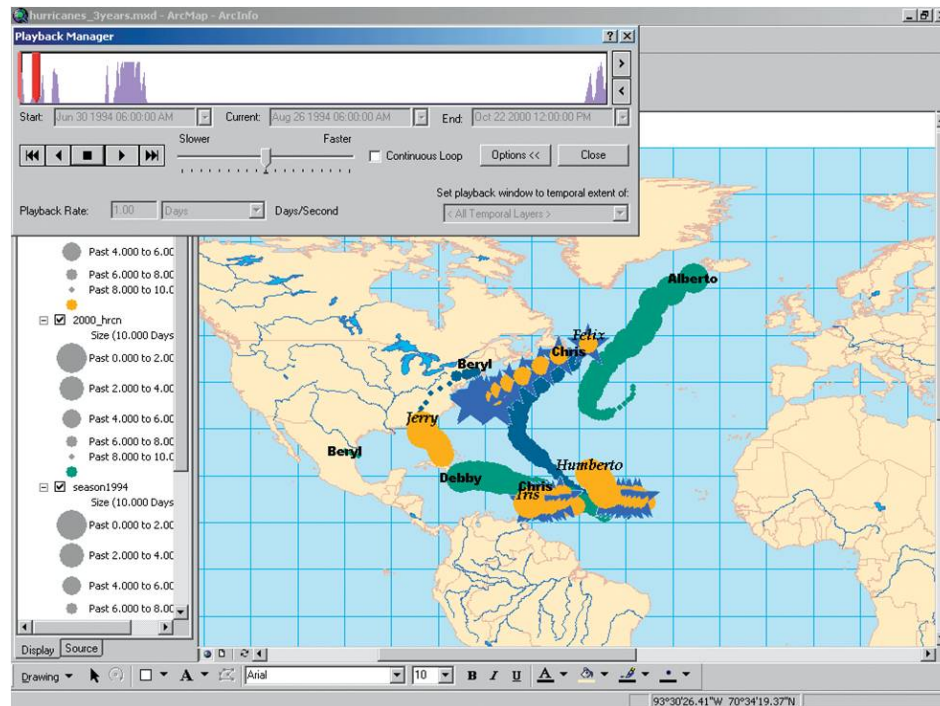
Figure 33.   Plotting of various hurricanes within a time period with ArcGIS tracking analyst toolset[133]

4.   3D Analyst Tools

Viewing data in three dimensions, also referred as 3D mapping, provides the analyst with new perspectives about the environment of the area to be analyzed. 3D views of maps "…provide insights that would not be readily apparent from a planimetric map of the same data."[134] For example, instead of

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[133] Retrieved from: http://www.esri.com/news/arcnews/summer02articles/introducing-arcgis-ta.html , (accessed date 8/26/2008).

[134] Liana Edmiston, Chris Belson and Walt Rennick, *Working with ArcGIS Spatial Analyst for Geospatial Intelligence (GEOINT) Supplement; Course Lectures*, 2.2nd ed. (Redlands, CA: ESRI educational services, 2005), 12-3.

trying to find the steeper slopes in a 2D map in order to be avoided, or seized, by ground forces, the analysts and decision makers can actually see the slopes and perceive the steepness and difference among elevations of the area of operations, Figure 34.
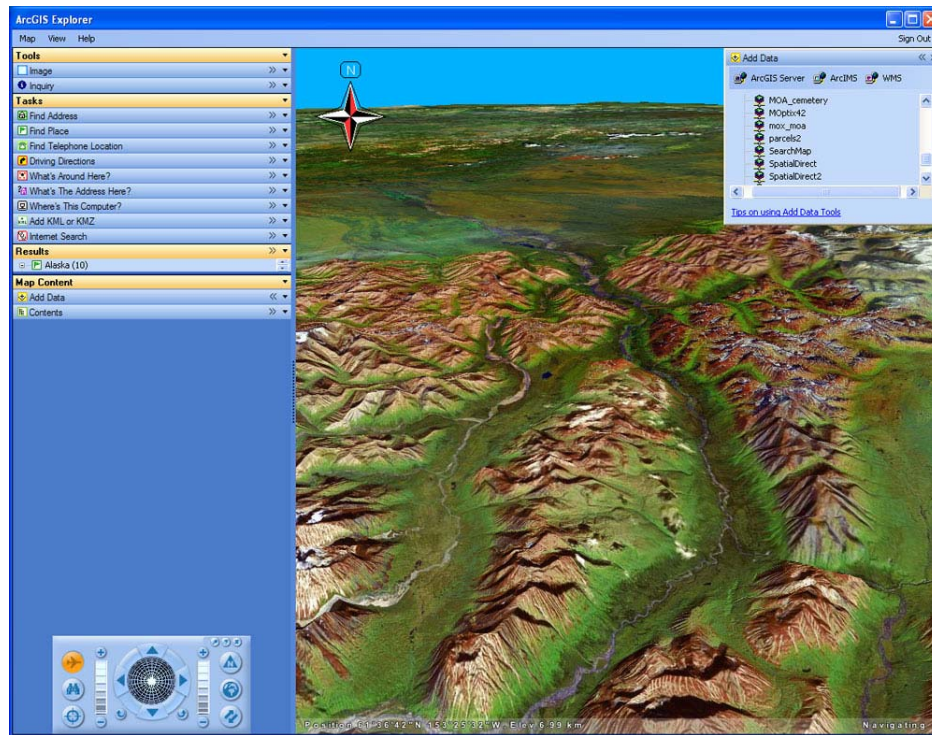
Figure 34.   3D map in ArcGIS Explorer[135]

3D analysis is important for military and intelligence analysts because it allows them to present the area of operations to the decision-makers in a very realistic way. This also allows the use of different features that take into account the surface in the area such as the signals' propagation for using or interception of communication devices, viewshed for covering from sight or for the establishment of observation points, and line of sight, among others. In addition,

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[135] Retrieved from: http://surveying-mapping-gis.blogspot.com/2005/12/speaking-of-google.html , (accessed date 8/27/2008).

the data manager can create or insert 3D objects such as buildings, installations, vehicles, and persons among others, in their real dimensions and put them in a given geographic position, Figure 35.

Figure 35.   A 3D computerized virtual environment created by geospatial engineers that resembles and urban tactical planner[136]

In addition, by means of 3D analysis, the analyst is able to present a building in 3D just showing external features or, in some singular cases, including the building's interior features, which allows for the navigation of the inside of the building. This property provides the military units that may operate in urban terrain, with a realistic COP to analyze, for example, snipers' allocations or tactical movements, among many others.

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136 Retrieved from: ESRI, "Mil Intel Muster Magazine", Fall 2007.

Furthermore, 3D analysis, which can be conducted using ArcGIS's 3D extension, ArcScene, and ArcGlobe, can be combined with the tracking analyst extension. This may allow the analyst to provide a 4D presentation of the COP to the decision-makers or to offer a simulation of past or future operations, Figure 36.
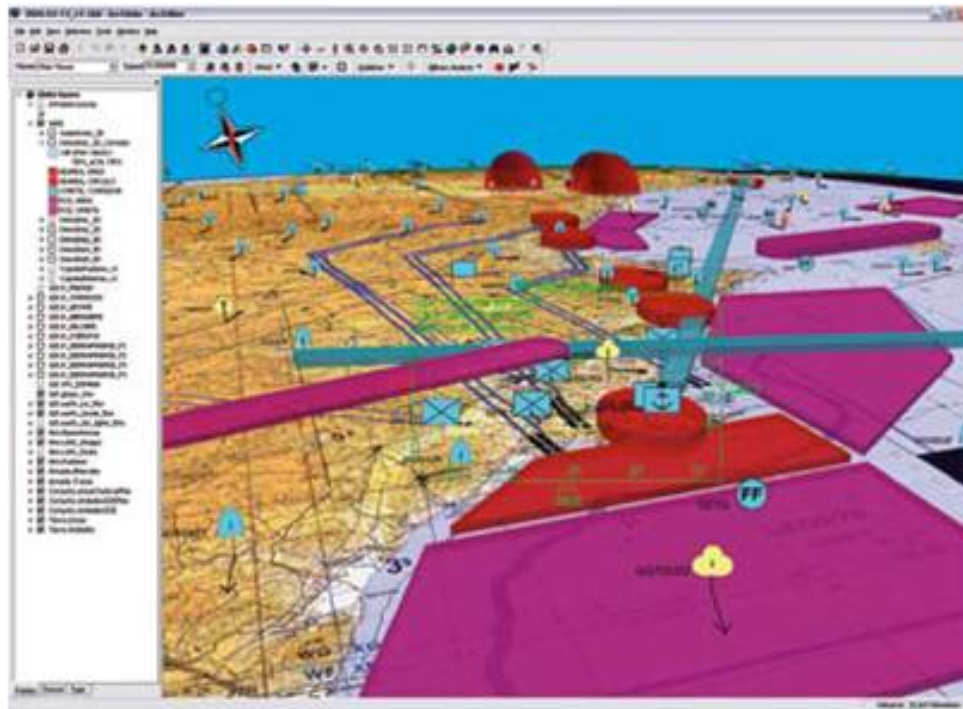
Figure 36. COP with 3D objects and showing the military symbols of the units in the area (created by the Spanish armed forces)[137]

B.   GIS PRACTICAL APPLICATIONS FOR THE MEXICAN NAVY

This section briefly examines some examples of practical applications of GIS in different military disciplines. Though the author focuses on those applications that may be useful for the Mexican Navy, they are not Mexican-Navy-exclusive-applications.

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[137] Retrieved from: ESRI "GIS in the Defense and Intelligence Communities" vol. 3.

1. Signals' Propagation

Simple calculations for signal's propagation that is based on line of sight such as VHF communications can be calculated by executing viewshed (a.k.a. visibility analysis or "radiate"), observer points, or line of sight tool in ArcGIS. Previous surface analysis is required to present the configuration of the area with characteristics such as elevation, vegetation, and buildings that could interfere in the signal's path. This provides the analyst with the capability for presenting the decision makers with a map of suitability areas for an effective communication among military units that would execute operations there, according to the characteristics of the communication devices and antennas.

On the other hand, when it comes to analyzing signals' propagation that are not based on line of sight, ArcGIS is compatible with other software packages that do. For example, "Cellular Expert" provides the analyst with line of sight communication analysis, tools to plan the installation of Universal Mobil Telecommunications System (UMTS) networks, and with mapping of signal propagation in a geographic area that illustrates data such as intensity, dead spots, and statistics, among others. This program also considers the buildings penetration of the signals,[138] Figure 37.

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[138] Cellular Expert, "White Paper," http://www.cellular-expert.com/DesktopDefault.aspx?tabID=3338&alias=cellular-expert&lang=en-US (accessed date 8/28/2008).
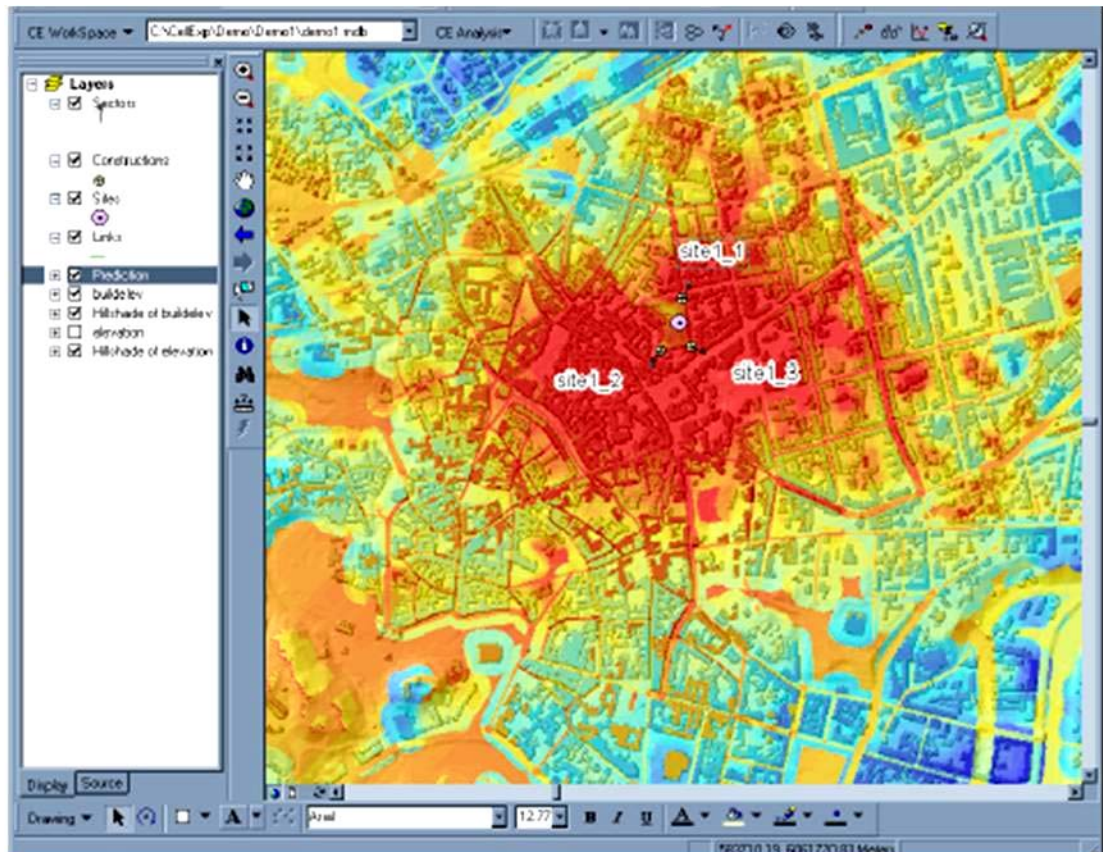
Figure 37.   **Field strength coverage prediction obtained by joining "Cellular Expert" application with ArcGIS[139]**

The aforementioned application allows the GEOINT analyst to develop 3D representations for analysis by means of ArcScene[140] that may allow the military to plan the collection of intelligence by establishing the best position to intercept communications from a known allocation of the target, not only on the ground but also with aerial devices. It also would allow establishing likely allocations of the target by computing the intensity and other data collected about interception of communications, Figure 38.

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[139] Retrieved from: http://www.cellular-expert.com/downloads/CE34whitepaper.pdf , (accessed date 8/28/2008).

[140] Cellular Expert, "White Paper," http://www.cellular-expert.com/DesktopDefault.aspx?tabID=3338&alias=cellular-expert&lang=en-US (accessed date 8/28/2008).
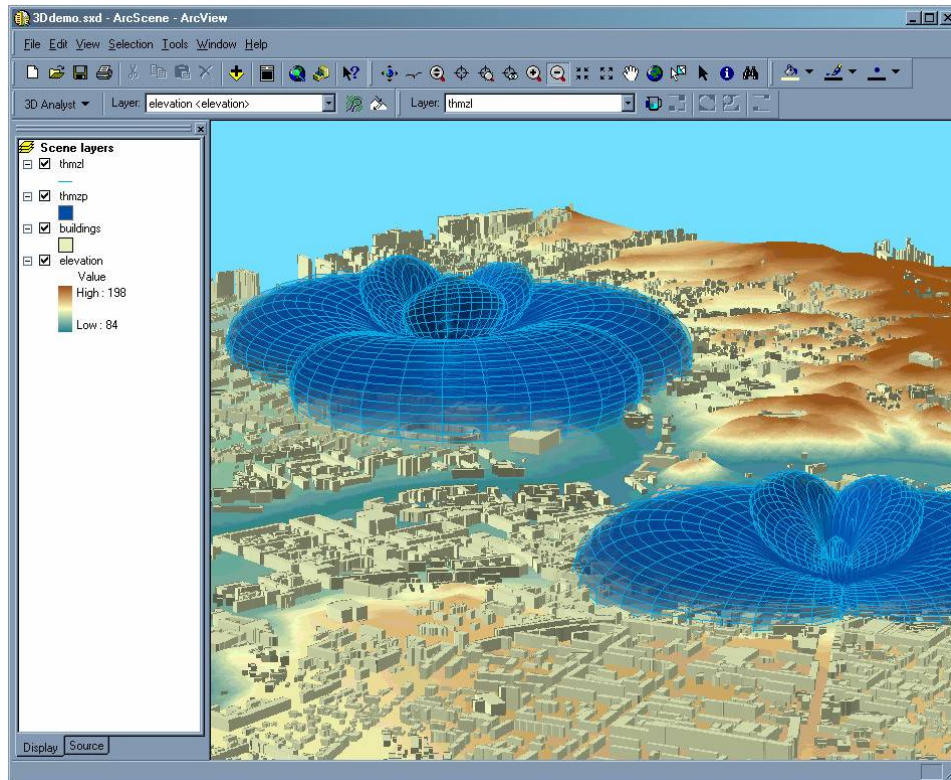
Figure 38.   3D antenna pattern visualization[141]

Communication System Planning Tools (CSPT), commonly known as "RF analyst" in the U.S. Defense community, are part of a toolset that has the capability to incorporate "…existing and planned wave prediction models." The RF analyst consists of three extensions: CSPT_LFMF, which covers low frequency/medium frequency (LFMF) in a spectrum that ranges from 150 KHz to 2 MHz. CSPT_HF, which covers high frequency (HF) in a spectrum that ranges from 2 MHz to 20 MHz. In addition, CSPT_VHF, which covers VHF/UHF in a spectrum that ranges from 20 MHz to 20 GHz. The principal purpose of these extensions is to support the military analyst in planning and predicting communication networks to help the decision makers in the planning and performance of their missions.

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141 Retrieved from: http://www.cellular-expert.com/downloads/CE34whitepaper.pdf , (accessed date 26/8/2008).

Hence, with these samples one could argue that the GIS may provide a platform for the Mexican Navy in executing Multi-INT operations in the field of signals' propagation, because it provides the intelligence analyst with the tools for combining HUMINT, SIGINT, MASINT, and putting them in geographical context (GEOINT). In addition, GIS may provide the analyst with a tool for planning communication networks in military operations.

2.   Ground Operations

For the military forces on the ground, the Spatial / Analyst / Surface tool provides a broad range of calculations to represent the terrain where forces may need to execute their operations. Considering the slope calculations for every single pixel in the digital map, alone, is a benefit that otherwise would require, from the analyst, the development of complex and time-consuming calculations that would hardly give the degree of accuracy gotten with GIS. In addition, representing the terrain in 3D view, allows the decision makers to perceive some degree of reality on the ground that may not be possible with a 2D map or image.. This capability, consequently, may allow military forces to make many decisions that are more effective over the ground forces with a priceless saving of human, material, and time resources. Figure 39 and Figure 40 illustrate the difference among 2D and 3D map perspectives.
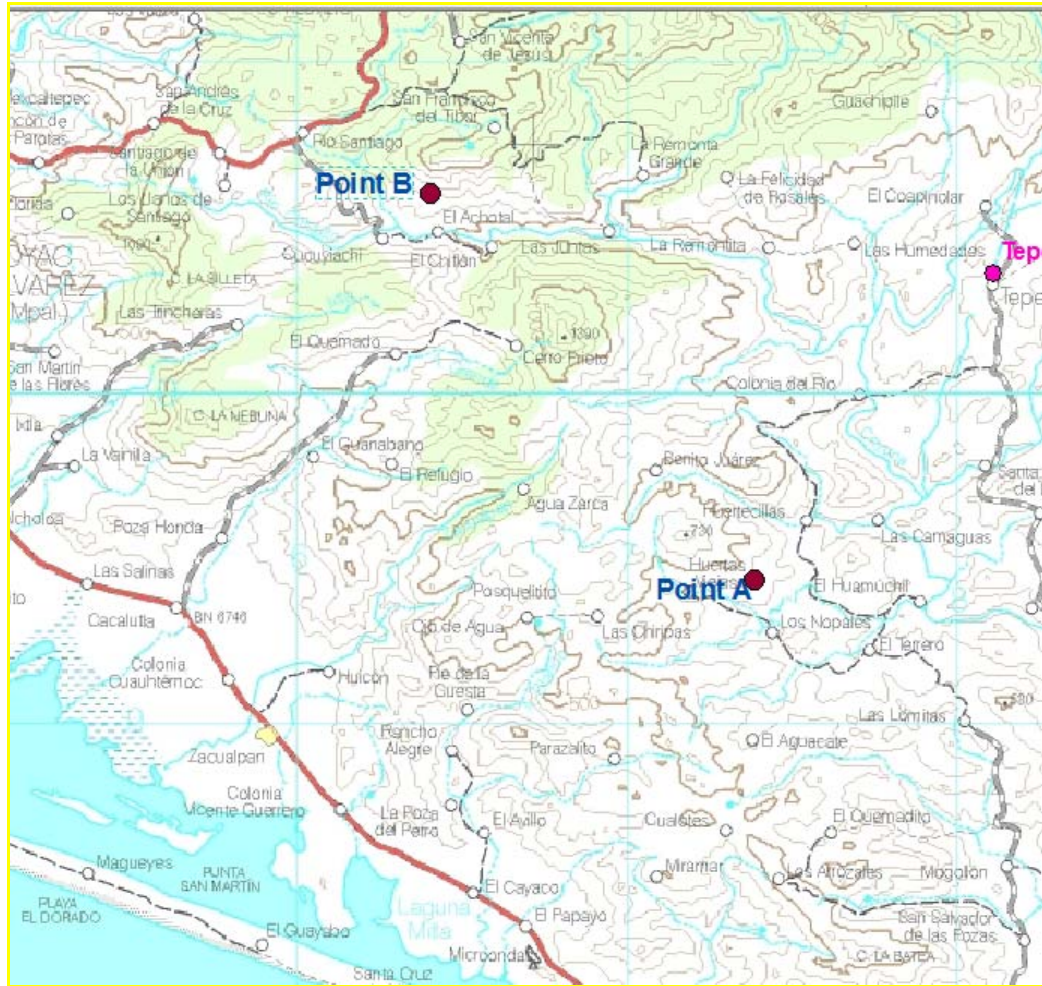
Figure 39.   2D map. The Commander must decide which route the military forces (A) will take to get to the point B.
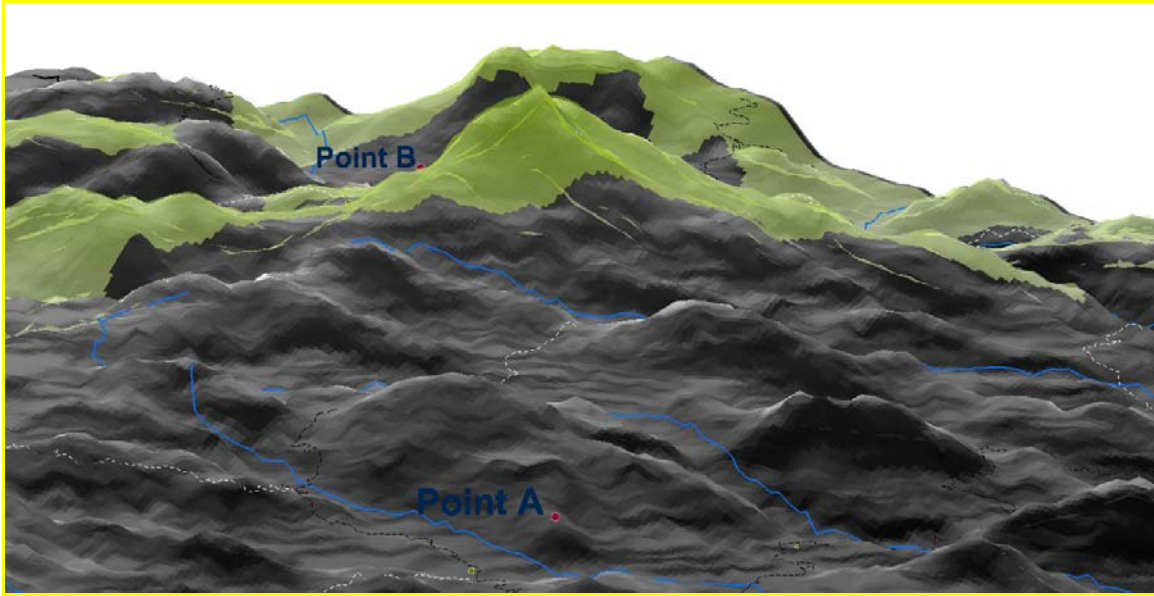
Figure 40.   3D map (same geographic area than map in Figure 39). The Commander must decide which route the military forces (Point A) will take to get to the point B (a different perspective for supporting his/her decision)

An important use for the Mexican Navy infantry is the GIS capability of providing the analyst with information such as adequate beachhead for disembarking purposes. In that respect, surface analysis may be developed by the GEOINT analyst by means of GIS and information such as gradient of the beach and soil type of the bottom of the sea.

3.   Air Operations

GIS provides the platform for the military forces to establish tactical control measures of the operational area that can be used by all the forces involved in a mission's execution. By means of these measures, air forces can establish their flight missions in the area in accordance with the COP and with situational awareness over the allied and enemy forces on the ground. This capability provides the aircraft with accurate information for purposes such as providing close air support and surveillance. Additionally, air forces may benefit from 3D

visualization when they require executing low altitude flight patterns to avoid being detected by enemy forces, Figure 41.

Figure 41.   3D map with tactical control measures to be used by air forces in the operational area[142]

4.   Sea Operations

By means of GIS and related extensions, analysts can provide with interactive digital maps for safe maritime navigation and situational awareness. This can be obtained by providing maps with different layers that represent the navigational hazards, bathymetry, magnetic declination, predominant streams and wind, maritime infrastructure, positions of the allied forces and enemy forces, and navigational aids, as well as others in the operational area, Figure 42. These layers could be used as standalone or in combination in order to ascertain the overall picture of the navigation area.[143]

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[142] Retrieved from: ESRI, "Mil Intel Muster Magazine", Fall 2007.

[143] United States, "Installation and Environment; U.S. Army/U.S. Marine Corps Range Managers Toolkit," *GIS in Defense and Intelligence Communities,* 2007, http://www.businessmap.com/library/brochures/pdfs/gis-in-defense-vol4.pdf (accessed date 8/29/2008).

Figure 42.   Maritime navigational digital chart showing different data layers to provide navigation's safety and situational awareness[144]

As pointed out in the first chapter, the Mexican Navy's various tasks involve not only acting as a Navy but also as a Coast Guard, and in doing so their mission is to preserve human life at sea. Distress calls from vessels at risk as well as overdue vessels often demand an effective way to execute Search and Rescue (SAR) operations. Executing these operations without the right tool may unnecessarily consume large and costly amounts of time as well as human and material resources.

In this regard, GIS allows the analyst to input the pieces of data about the vessel and the predominant conditions in the vessel's Last Known Position (LKP) and to run pre-established mathematical models to predict the probable location of the vessel as well as search patterns to be executed by the Navy units, thus increasing their effectiveness.

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[144] Retrieved from: http://www.esri.com/industries/defense/files/gis-defense-navy-vol3.pdf , (accessed date 8/27/2008).

For example, one organization that maximizes SAR operations by means of GIS is the US Coast Guard (USCG), which counts on the Search and Rescue Optimal Planning System (SAROPS) that

> ...is a software system built on GIS technology. . . . GIS revolutionizes search planning and any mission with a geographic component. This holds whether the goal is to establish an optimal search plan or to geographically scrutinize the curious behavior of an inbound liquid natural gas carrier.[145] Figure 43
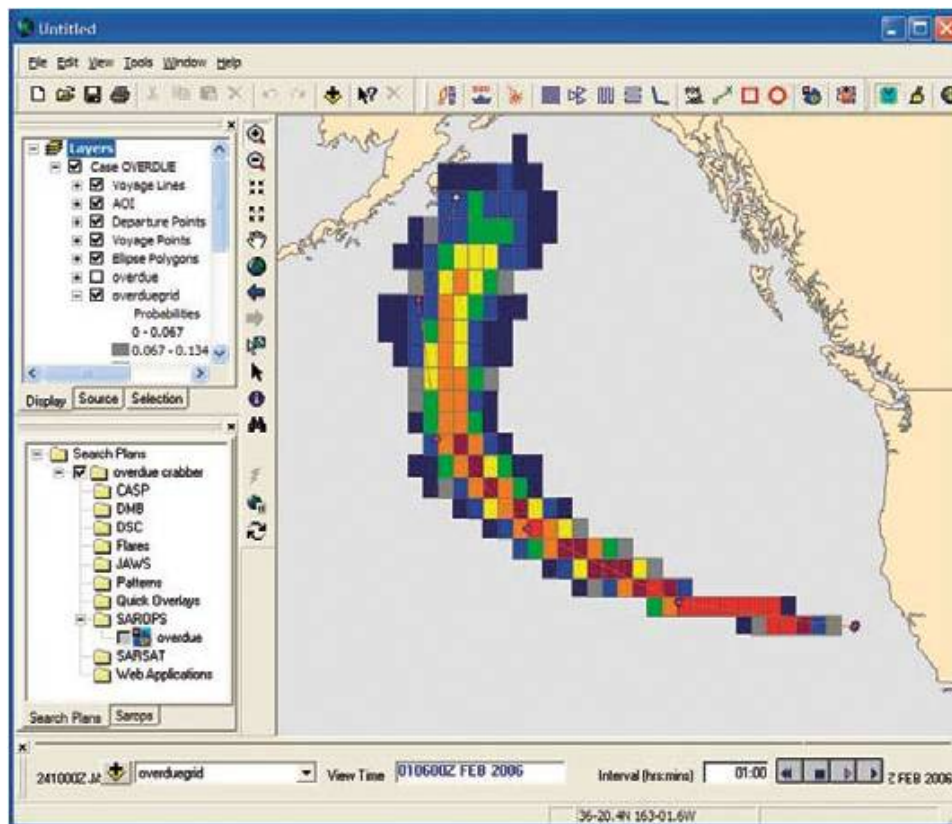
Figure 43.   An open ocean case with a long drift interval (the time between a search object's LKP and the searcher's on-scene time) can easily require the expenditure of hundreds of search hours over thousands of miles[146]

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[145] Retrieved from: http://www.esri.com/industries/defense/files/gis-defense-navy-vol3.pdf , (accessed date 8/27/2008).

[146] Retrieved from: http://www.geographymatters.com/library/brochures/pdfs/gis-in-defense-vol3.pdf , (accessed date 8/28/2008).

A particularly important feature of GIS is that, with the appropriate database system, it facilitates the storage and management of the data. For example, instead of dealing with large amounts of paper intelligence reports about the drug trafficking routes by the sea, the GEOINT analyst may have the capability to extract the information he/she needs to have for the analysis with every single detail associated with the drug trafficking route to be analyzed (or whatever features he/she needs to analyze). In addition, all of the information required for the analysis can be represented geospatially. Hence, by selecting one route the analyst could have the name of the ship and captain, the port of origin, the geographic position of the capture, the points of the itinerary, and the date and time of various geographic positions in a given route. The system also allows one to add new data to a given feature obtained by a given source of intelligence. This makes the GIS increasingly valuable as time goes by because the more time the GIS is used by a given organization, the more data it has in its database and more accurate patterns can emerge from a given analysis.

As noted in the last section, ArcGIS analytical software also provides GEOINT analysts with many statistical algorithms that allow them to develop "pattern analysis." For example, "Line Density," which could allow the Mexican Navy being proactive in the execution of patrolling the Mexican seas to intercept drug-traffickers' ships.

Figure 44 to Figure 46 illustrate a very basic process of pattern analysis by applying geospatial statistics through means of the ArcGIS Line-Density tool. The GIS operation was developed by the author of this thesis and as such is a hypothetical situation where the GEOINT analyst counts on the routes of suspicious medium draft boats arriving in Mexican waters within a given period. The Commander ordered the GEOINT analyst to determine the areas on which to focus in patrolling the Mexican Seas on the Pacific coast. It is worth noting that

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for purposes of illustration, the example routes are limited, in real world application they could be hundreds or even thousands, depending on the period and the intelligence available.
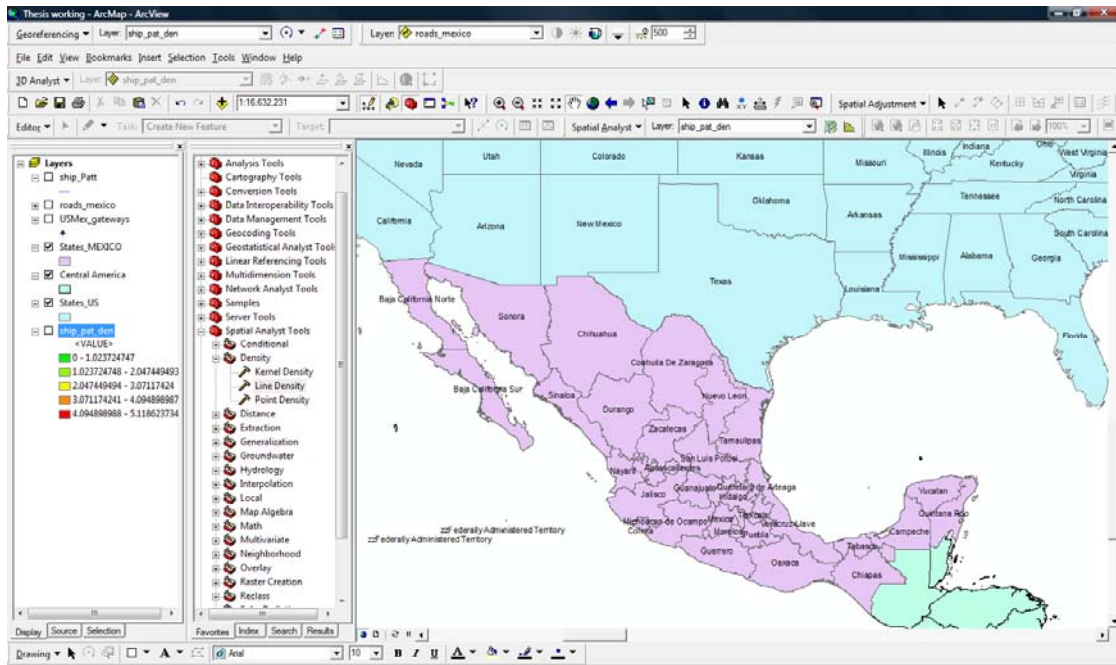
Figure 44.   Vector-based map of Mexico, part of U.S., and Central America
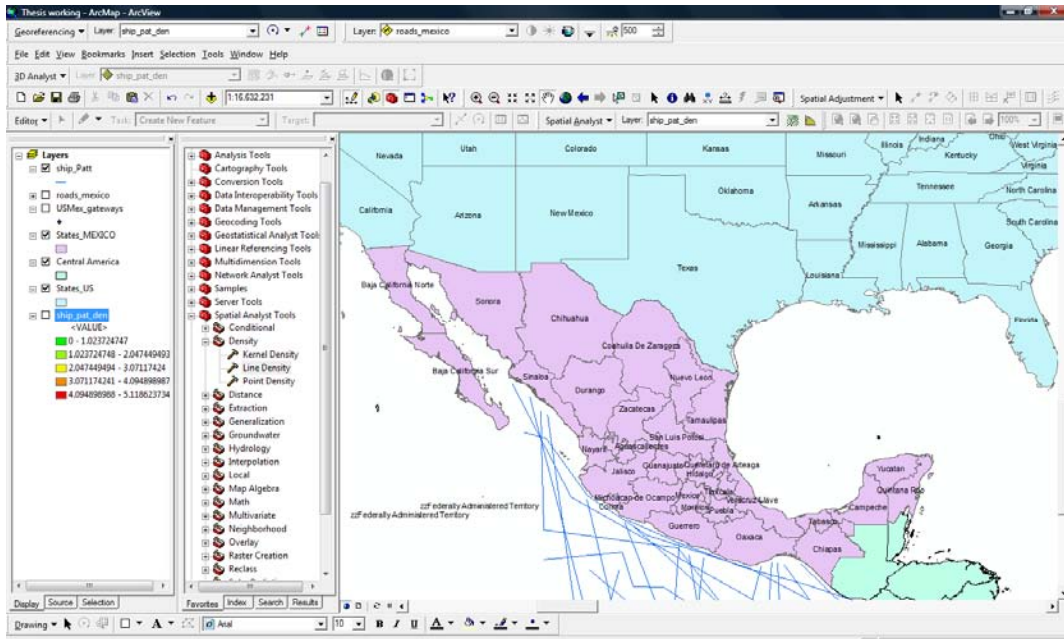
Figure 45. Map of Mexico when adding the "routes" layer (blue lines in the Pacific coast) that represents suspicious medium draft boats arriving in Mexican waters in a given period.
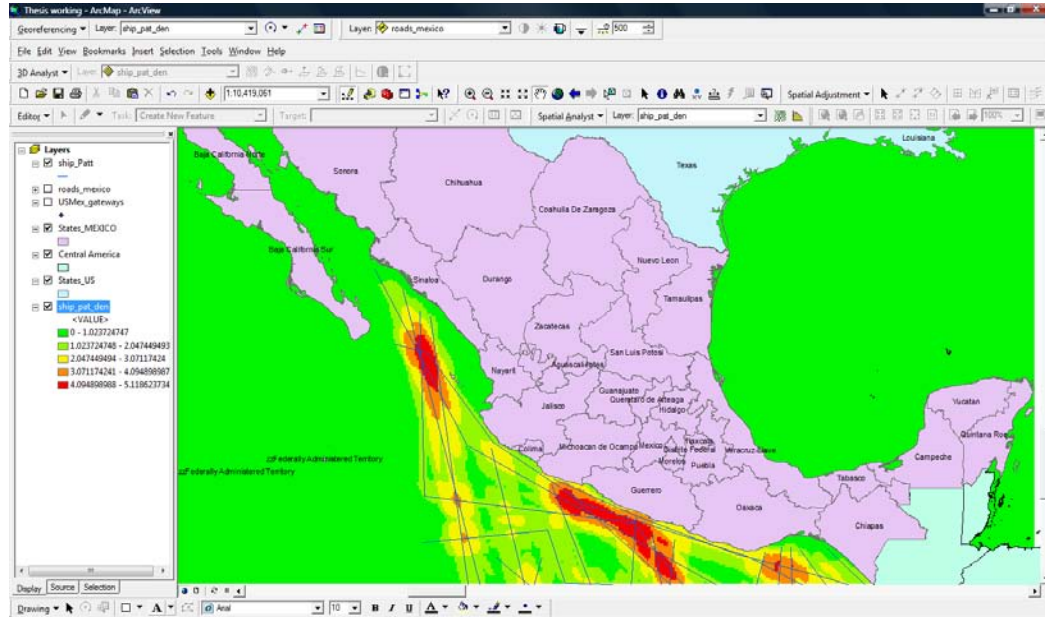
Figure 46. "Density" layer added to the map, the ramp color is green (less density) to red (more density). Thus, red spots represent the areas of major traffic of suspicions boats over the given period

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5. Combat Systems

GIS offers tools for establishing a radius of action of different military units depending on the range of their weapons; this allows the analyst to consider effective positions of our own forces or risk areas regarding to the enemy's weapons. The basic operation for doing so is "buffering" which consists of establishing the different ranges as inputs and creates circles around the weapon according to that input. In addition, there are operations such as viewshed that can be used to establish parameters of effectiveness of the weapons given by visibility, the ranges of a given weapon, as well as the target's position.

Furthermore, some institutions have developed specific extensions that offer more complex analysis that take into account many other factors. For example, the U.S. Army / U.S. Marine Range Managers Toolkit (RMTK), supports the planning, organization, and development of range safety as well as "…planning of individual and combined live fire training events."[147] In addition

> The core capability of RMTK is the creation of Surface Danger Zones (SDZ) for any weapon in the army and marine inventory. The SDZ generator is a wizard-driven tool that collects information about weapons, ammunition, and target and firing conditions and creates unique SDZ feature.[148] Figure 47

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[147] United States, "Installation and Environment; U.S. Army/U.S. Marine Corps Range Managers Toolkit," *GIS in Defense and Intelligence Communities,* 2007, http://www.businessmap.com/library/brochures/pdfs/gis-in-defense-vol4.pdf (accessed date 8/29/2008).

[148] Ibid.29
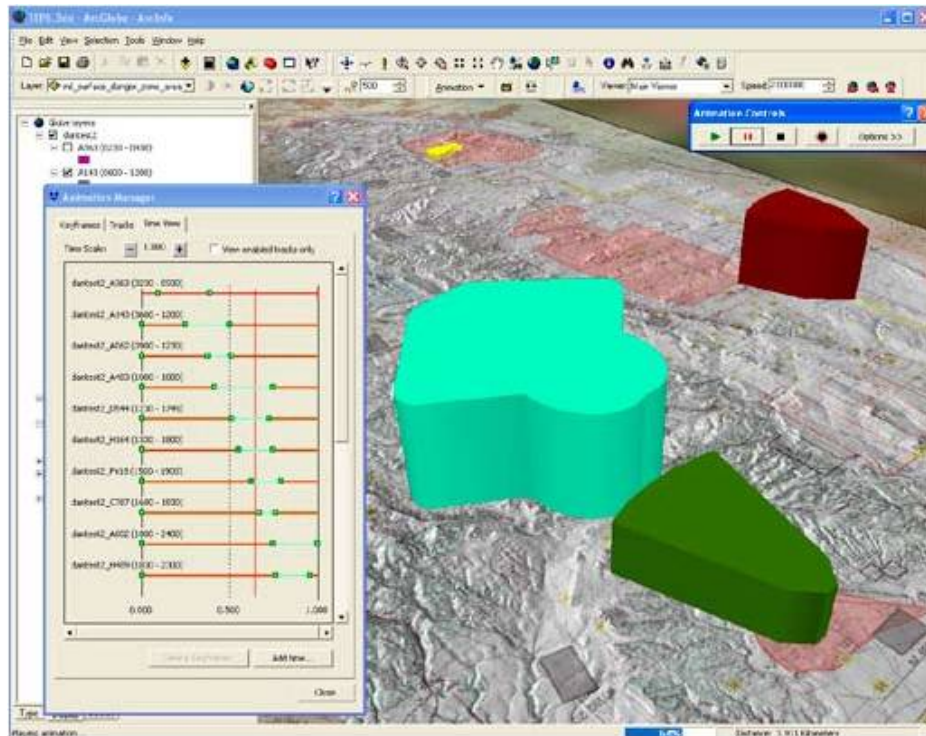
Figure 47.   A 3D hazards animation with the Training Event Planning System from RMTK

6.   National Security Affairs

GEOINT analysts are able to produce valuable intelligence for assessing decision makers in National Security Affairs (NSA) by means of GIS. Therefore, GIS provides the analyst with the ability to integrate OSINT of statistical data about demography, economy, politics, crime, social movements, communications, and polls among many others and combining it with any other intelligence products available.

By taking as an example one of the biggest threats to Mexican national Security, which is the drug-related violence, some basic maps were developed by means of ArcGIS, Figure 48 to Figure 50. These maps are derived from the collection of OSINT and then captured in excel tables, in the case of statistics, and directly captured in ArcGIS, in the case of image or other type of data. This

kind of map allows the GEOINT analyst to keep the decision makers informed of the current National Security situation concerning specific factors. A map is much easier to understand and analyze than a large amount of paper with a large amount of numbers and data. In addition, these maps can be useful to the commanders for providing good National security assessment and/or orientation to upper levels.

OBJECTID *	Shape *	ST_NAME	ST_ID	SQKM	Shape_Length	Shape_Area	Pop_2005	DrugHomic 2006	DrugHomic200	DHom2006/2007
1	Polygon	Sonora	26	181672.406	40.837565	16.920561	2394861	61	123	184
2	Polygon	Chihuahua	8	246454.703	30.142775	22.754243	3241444	130	150	280
3	Polygon	Baja California Norte	2	73210.75	27.668162	6.877702	2844469	163	151	314
4	Polygon	Coahuila De Zaragoza	5	150983.906	24.550833	13.745974	2495200	18	30	48
5	Polygon	Baja California Sur	3	72205.328	45.957501	6.495109	512170	7	7	14
6	Polygon	Durango	10	123384.203	23.159156	11.005466	1509117	64	131	195
7	Polygon	Nuevo Leon	19	64639.102	19.870139	5.797051	4199292	50	110	160
8	Polygon	Sinaloa	25	56090.672	37.765301	5.00664	2608442	350	343	693
9	Polygon	Tamaulipas	28	77979.508	46.494247	6.919345	3024238	181	85	266
10	Polygon	San Luis Potosi	24	61505.648	19.529833	5.387929	2410414	9	16	25
12	Polygon	Aguascalientes	1	5621.74	3.635783	0.490411	1065416	5	30	35
13	Polygon	Veracruz-Llave	30	71456.703	34.8043	6.127857	7110214	25	43	68
14	Polygon	Quintana Roo	23	43497.16	30.343955	3.735605	1135309	11	33	44
15	Polygon	Zacatecas	32	75971.617	28.140191	6.691446	1367692	16	16	32
16	Polygon	Jalisco	14	79076.188	30.878901	6.832306	6752113	45	90	135
17	Polygon	Hidalgo	13	20986.09	12.506006	1.81182	2345514	19	38	57
18	Polygon	Queretaro de Arteaga	22	11576.48	7.83279	1.001955	1598139	0	10	10
19	Polygon	Nayarit	18	28198.07	13.476396	2.456434	949684	10	10	20
20	Polygon	Yucatan	31	39462.07	14.53628	3.412942	1818948	0	4	4
21	Polygon	Campeche	4	56199.469	19.838709	4.803339	754730	12	10	22
22	Polygon	Puebla	21	34136.219	18.498696	2.920342	5383133	11	9	20
23	Polygon	Guanajuato	11	30415.561	11.87159	2.633381	4893812	21	40	61
24	Polygon	Michoacan de Ocampo	16	58986.84	17.88774	5.052212	3966073	543	240	783
25	Polygon	Mexico	15	22392.881	11.672598	1.91961	14007495	31	111	142
26	Polygon	Colima	6	5619.036	4.572433	0.481049	567996	4	0	4
27	Polygon	Distrito Federal	9	1505.781	1.811729	0.129019	8720916	137	147	284
28	Polygon	Tlaxcala	29	3997.477	3.586921	0.342835	1068207	0	5	5
29	Polygon	Morelos	17	4854.627	3.751569	0.414618	1612899	11	19	30
30	Polygon	Guerrero	12	63771.859	16.637397	5.413325	3115202	186	255	441
31	Polygon	Tabasco	27	24603.971	14.425088	2.09157	1989969	21	23	44
32	Polygon	Chiapas	7	73934.406	17.100168	6.236581	4293459	19	15	34
33	Polygon	Oaxaca	20	92923.148	24.117837	7.857948	3506821	19	33	52

Figure 48. Data about drug-related homicides in Mexico during 2006 and 2007, population 2005 per State, and others. Captured in excel and transformed into DBF table to work with ArcGIS

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Drug-Related Homicides Rates per Mexican State during 2006 and 2007 Normalized by Population 2005
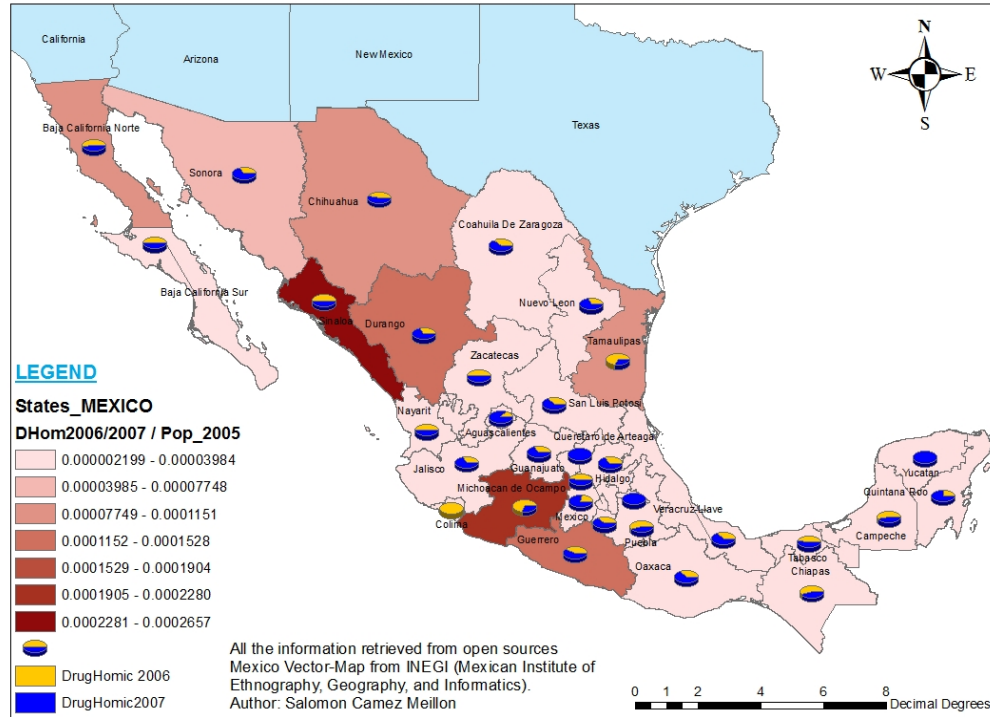
Figure 49. (Drug-Related Homicides Rates in Mexico) Author's final map-product that resulted from joining the DBF table with the attribute table of Mexico's vector-map as well as developing the steps to get the geographic representation of statistical data.
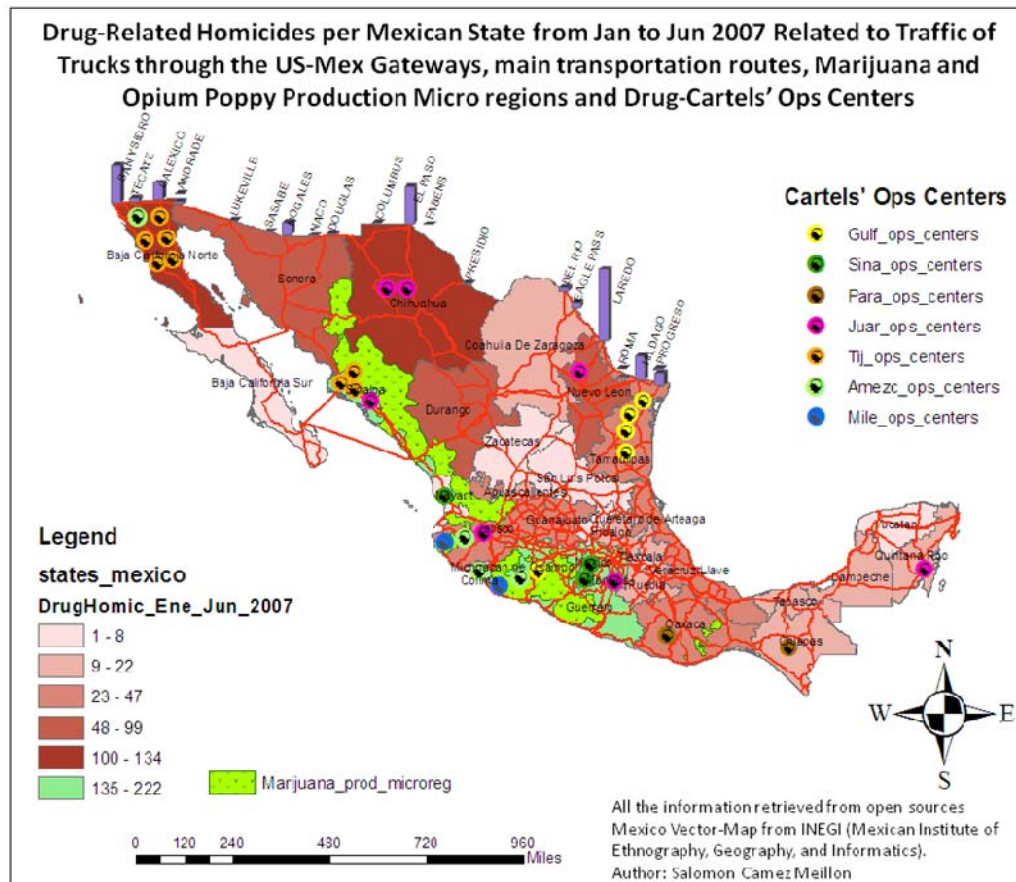
Figure 50.   **Author's Map-product representing the combination (layering) of statistical data and other information related to the phenomenon of drug-related-violence in Mexico**

One important characteristic of GIS analytical software in the intelligence field, particularly in the NSA, is that its potential can be significantly multiplied by combining it with other analytical software such as the ones used to develop link analysis or crime investigation. One that is being used by many of the U.S. armed forces units, U.S. intelligence entities, and other U.S. government agencies such as the DEA and FBI is "i2" investigative analysis software that mainly relies on network (i.e. social network, commodity flow, communications, financial etc.) and visual analysis.

Hence, i2 enables the analyst to turn large volumes of disparate data into actionable intelligence by identifying hidden patterns and connections within large datasets. A significant capability in this regard is that i2 allows the analyst to extract information from text data such as large amounts of intelligence reports and building relationships among the multiple data within those text files, Figure 51. In addition, this software allows the analyst to present complex cases with intuitive briefing charts and reports. The field where this software is useful ranges from insurance or credit card frauds, identity theft, and money laundering to military investigation, organized crime, and counterterrorism. i2 can interface with ArcGIS, integrating geospatial analysis to investigative analysis; as a consequence, they multiply their capabilities to one another, Figure 52.[149]
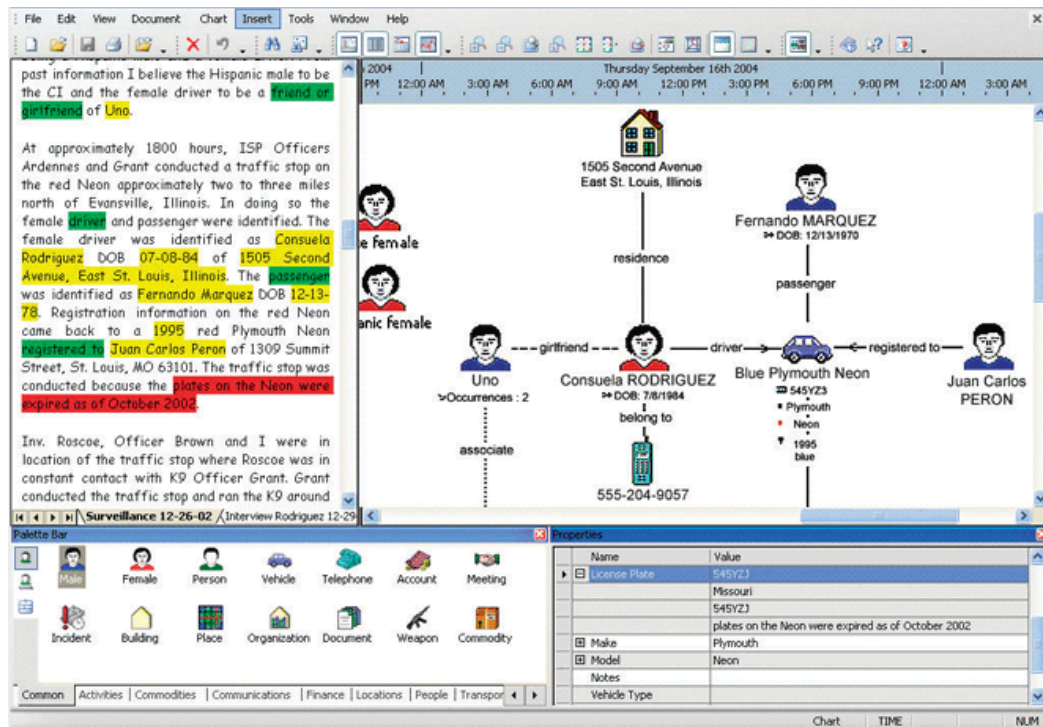
Figure 51.   Text format (upper left) visualized as a network for investigation (upper right) by means of i2 investigative-analysis software.

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149 "Solutions » Solutions » i2: Investigative Analysis Software," http://www.i2inc.com/solutions/ (accessed date 8/29/2008).
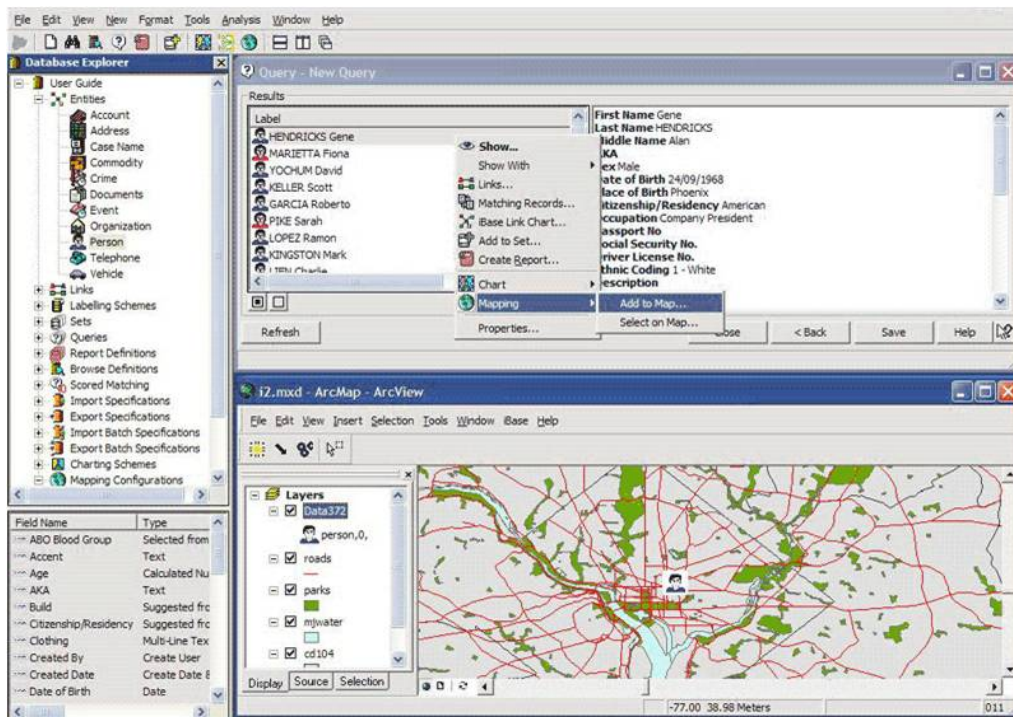
Figure 52.   ArCGIS and i2 interfacing in an investigative analysis.

7.   Command & Control (C2), Operational Training Exercises, and Simulation

The basis for an effective performance of the Mexican Navy relies on training its people. Hence, in maintaining their operational capability, Mexican Navy components constantly execute large-scale training exercises that involve sea, land, and air operations, in which complexity, as in a real operation, often requires an effective C^2 that guarantees high level of interoperability. Consequently, GIS may provide the headquarters of the training's operation with the required tools for information-integration and the components' efforts, as well as with the capability for storing and organizing the information retrieved from situation and intelligence reports sent by the various units.

This may allow the analyst to provide the COP to the Commander and staff in "real time" and in an interactive way, which means presenting specifically what the commander needs to know in a given time, for example, just presenting

in the display or in a printed map the recent movements or just the movements of compromised forces.[150] This ability may also allow the training arbiters to manipulate the forces with the purpose of fulfilling training objectives.

When finishing the exercises, the arbiters' analysts may upload the data from the pre-assigned GPS devices from every participating unit. This may have the purpose of filling the informational gaps and verifying the results of the GIS and analysts' performance. In this regard, there exist free online interfaces that allow the upload of GPS tracked itineraries to ArcGIS by means of a PC – GPS physical connection,[151] Figure 53.
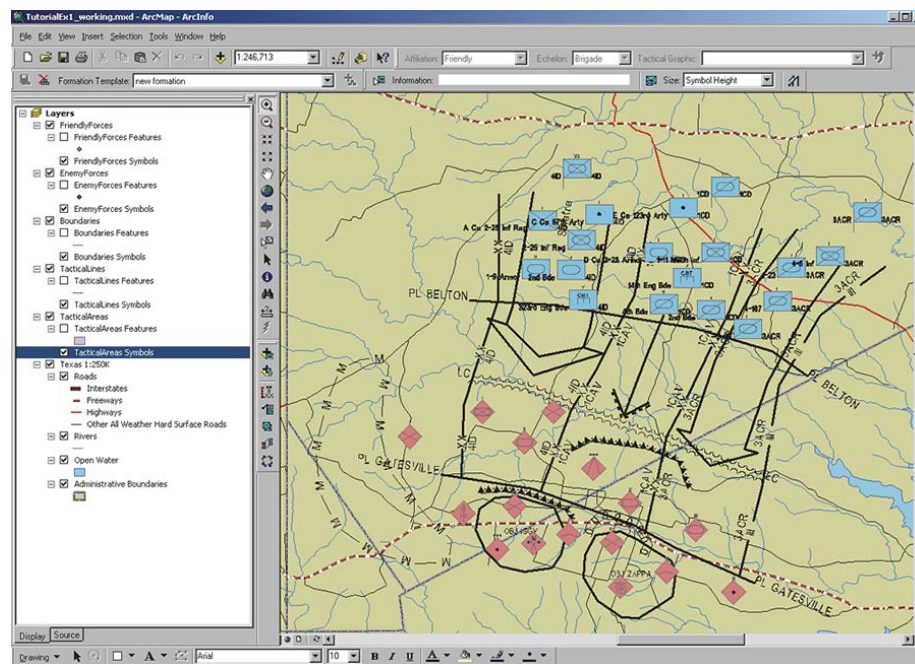
Figure 53.   2D map with a basic example of a COP that depicts blue forces and red forces' military symbols as well as the tactical control measures on the battlefield by means of MOLE extension.

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[150] Furthermore, a military force relying on the capability of integrating its navigation devices such as GPS in a system that automatically sends the information by means of satellite to the headquarters may not have to deal with the capture of data sent by the units. Hence, GIS can offer the COP in real time.

[151] When the arbiters and analyst require post-tracking from the various units, they have to pre-assign trackers in these components. They would obviously be trackers with a GPS device whose task, besides his/her tasks assigned within the unit, would be to monitor the unit by means of the GPS. The task would involve pushing the "mark" GPS button every given period.

In sum, the applications of GIS in the military and intelligence fields are almost limitless. However, because the purpose of this section is to offer an overview that provides an understanding of GIS's enormous potential, the applications presented were not exhaustive. There are many other military and intelligence uses for GIS, such as developing analysis in planning "strategic infrastructure protection" –by developing suitability analysis based on potential risks and other factors in the environment and by setting up evacuation plans of the people and valuable material at risk. In addition, in relation to the application of GIS in Special Operations, an example of the execution of the GEOINT process using GIS through a hypothetical scenario will be provided in the next chapter.

To conclude, GIS analytical software provides GEOINT analysts and commanders in the military and intelligence fields with a very powerful and practical tool. However, because the applications of GIS in these fields are almost limitless, establishing the GIS organization and structure to make the most of these applications in the Mexican Navy is a complex task. Consequently, it would require a sound and very well planned project implementation, which demands professional training for the GEOINT analysts, data managers, and system managers as well as an effective GIS' infrastructure as a primary goal.

IV. SCENARIO: GEOINT FOR THE MEXICAN NAVY SPECIAL OPERATIONS FORCES IN THEIR PLANNING FOR A RESCUE OPERATION IN HOSTILE TERRITORY

This chapter presents a hypothetical scenario in Mexico that requires an analysis of the factors involved to provide effective GEOINT to support the decision makers' and/or operational commanders' decisions. It has been developed through the GEOINT process' model presented in chapter II section D and using ArcGIS analytical software. In developing the present scenario, the author takes the role of the GEOINT analyst. This practical exercise attempts to illustrate the importance of the GEOINT in the intelligence and military fields. In addition, it hopes to demonstrate the significance of the Geospatial analysis component in the GEOINT process as well as the valuable support provided by ArcGIS analytical software in that activity. For those with knowledge regarding geospatial analysis **APPENDIX A** will provide details of some of the geospatial analysis' operations performed to get the results here presented.

Limitations: Due to the costs of getting the Mexican digital products, which are required by Mexico and their scarce availability in the U.S., some of the digital maps lack the scale and detail required for intelligence work and military operations. However, those available are adequate for educational purposes as well as to display the results of Geospatial analysis activities in the GEOINT process.

Due to security constraints, it is impossible to get imagery from the area of study that has the quality that is required for GEOINT; hence, the imagery and IMINT activities in the GEOINT process will be taken for granted. However, it is important to note that because this is a hypothetical scenario the actual imagery from the area would not reflect the situation here invented. Hence, the affectation given by that limitation is minimal for purposes of this work.

Therefore, it will be argued that the limitations in imagery will be helpful to show how Geospatial analysis is very significant in providing valuable support to the commanders in the decision making process and to demonstrate that Geospatial Analysis provides the GEOINT analyst with analytical capabilities not provided by images of the area of interest. However, the three GEOINT components (Geospatial Analysis, Imagery, and IMINT) reinforce each other and all must be exploited when available.

In spite of the fact that the following analysis is developed using real GIS products of Mexico (digital maps and geographic features), the problem will be a hypothetical (What If) scenario that has nothing to do with the current situation in that geographic area nor in any other location in Mexico.

A.   SCENARIO

The Mexican Navy High Command ordered the Pacific Navy Force the execution of a rescue operation to evacuate a Special Forces recon patrol formed by four soldiers because two of them had an accident suffering serious injuries that were not life-threatening but has caused them to be immobilized in a hostile area. Consequently, the injured soldiers require medical attention and extraction, as does the rest of the recon patrol.

The risk for the Navy forces in the area is high because the injured soldiers and the rest of the recon patrol are immobilized in the surrounding area of a guerrilla group's base of operations. In addition, the guerrilla members in the area have sometimes engaged military and police forces in that region. Moreover, operations in the area are constrained by a demilitarized zone on the ground and by a demilitarized-fly-over-zone in the airspace.

The high command informed the Pacific Navy Force Commander that the priority of the mission will be to rescue and to protect the physical integrity of the recon patrol; however, he emphasized that the rescue unit has to avoid any direct confrontation with the guerrilla forces. Additionally, he authorized the

landing of Navy helicopters in order to assure the quick evacuation of the forces, but the helicopters must land outside of the designated demilitarized-fly-over-zone and the insertion of the rescue force has to be completed in secrecy.

B.   INTELLIGENCE; ORIENTATION

The *Pueblo Unido contra la Opresion* PUO (United People against the Oppression) is a guerrilla movement that emerged in 2004 and claims that it is fighting for the rights of the indigenous population and the eradication of poverty in Mexico. However, many believe that this is just a cover to hide the real purpose of the movement's leaders, which is making a profit from criminal enterprises and destabilizing the Mexican State.

Since 2004, the movement has been responsible for a variety of attacks on military operational bases, the sabotage of oil pipelines, the killing of authorities, assaults, and kidnapping. In addition, there is strong evidence of a tie between the PUO and the Mexican drug cartels; indeed aerial reconnaissance in recent months found some marijuana crops in what is considered PUO's area of operation.

The Mexican government has been negotiating with the PUO since 2006, but negotiations have broken off three times. Despite truces declared by the PUO because of the negotiations, there is evidence that during those periods they have continued committing criminal acts.

Due to the negotiations, the Mexican government has designated a demilitarized zone on the ground that is a 4000 m radio circle from the geographic position of the village of *Tepetixtla*, *Guerrero* (UTM 17Q 381116.877971 _ 1903628.39436). This location is considered the PUO's base of operations; the government also has designated a demilitarized-fly-over-zone in the airspace in a 6500 m radio from the aforementioned geographic position.

According to intelligence reports, the PUO has four observation and checkpoint positions in that area, which are designated and located as follows:

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Point's name   Position in UTM coordinates

a. En_Obs 1: UTM 17Q 381116.877971 _ 1901151.67221
b. En_Obs 2: UTM 17Q 383733.791943 _ 1904983.58195
c. En_Obs 3: UTM 17Q 380602.841298 _ 1906432.23076
d. En_Obs 4: UTM 17Q 377985.927326 _ 1901432.05585

PUO vehicles (usually trucks) use the State-road that runs from *Coyuca de Benitez* to *Tepetixtla* and the dirt-roads that run from *Penjamo* to *Tepetixtla* through *Mogollon*, El *Terrero, Huertecitas*, and *Colonia del Rio* villages. Shootings have been reported from PUO's trucks on these paths.

The PUO standard weapon is Cal. 7.62 with a maximum range of 1000 m.

The geographic position of the recon patrol (Objective) is UTM 17Q 374788.22619 _ 1902721.92857.

C.   GEOINT PROCESS (FIRST CYCLE)

The Commander of the Pacific Navy Force ordered his Staff to present the COP of the intelligence provided by the High Command to support his decision about what kind of operation would be required to rescue the recon patrol; consequently, GEOINT analysts began developing the assigned task. [152] This involves six broad steps: 1) Planning and Direction, 2) Data Collection, 3) Processing and Exploitation, 4) Analysis and Production, 5) Dissemination and 6) Evaluation and Feedback. Each of these steps are discussed in turn.

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[152] The GEOINT analysis in this work will be reframed by the GEOINT process' model offered in chapter II of this thesis, so the reader may understand how each activity falls into that model and how it is applied in practice. In addition, imagery and IMINT are not developed in the present scenario, because the author do not count on imagery of the area, even so, because this is a hypothetical scenario the actual imagery of the area would not reveal the situation invented for this analysis. Therefore, imagery and IMINT are going to be taken for granted. However the exploitation of Geospatial analysis to solve the problem planted by the "what if" scenario may highlight the significance of that GEOINT component, which almost by itself (without the support of Imagery) may provide excellent support for the decision makers in this case.

1. Planning and Direction

Geospatial analysis and IMINT activities

Define the problem: Presenting the COP to the Navy Force Commander with the intelligence provided by the High Command.

Define GIS criteria: To be able to provide the Navy Force Commander with the COP required at this stage, the GEOINT analyst may require information products such as topographic maps of the area and surroundings, as well as a Digital Elevation Model (DEM) of the area of interest. These products may provide geographic and topographic details of the area of interest and its surroundings to the analysts and decision-makers.[153]

Submit required information products: digital maps not available in the database, may be required from the *Instituto Nacional de Estadística y Geografía,* INEGI (National Institute of Statistics and Geography, Mexico). In addition, the satellite images, if not available, may be required by the SIS.

Imagery activity

Officers in charge of imagery (SIS) may receive the requests of satellite and aerial imagery from the analysts and they may coordinate with the various imagery collection systems involved to get the required products that are not currently in its database.

The Direction side of "Planning and Direction" is interrelated to "evaluation and feedback." In this component of the process the GEOINT officer or officers assigned as managers of a given analysis may control the workflow and synchronize efforts of all the elements and analysts involved. That may be done during every step of the GEOINT process.

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[153] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 1** on p. **189** for further details on the geospatial analysis operations developed at this stage

2.   Collection

Geospatial analysis activity

Import information products: the Geospatial analysts gather the information products required in the previous step from the entities involved.

Build raw dataset: the "geospatial raw dataset" is organized into files for being uploaded into the GIS and processed in later steps. Figure 54 and Figure 55 illustrate the information products collected in this step.

Digital Georeferenced Map E 14c46, scale 1/50000 (TIF)

Digital Georeferenced Map E 1407, scale 1/250000 (TIF)

Digital Georeferenced Map E 1408, scale 1/250000 (TIF)

Digital Georeferenced Map E 1411, scale 1/250000 (TIF)
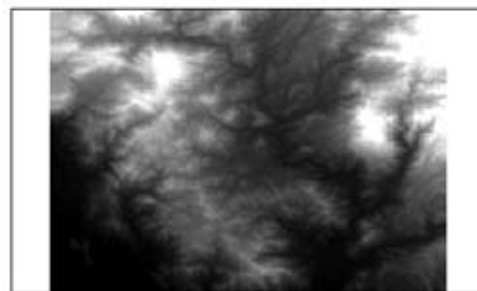
Digital Elevation Model (DEM) E14c46 1/50000

Figure 54.   Digital Information Products collected and forming the "raw dataset" into the GIS (Part 1/2)

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Villages, point feature class for E14c46 area, scale 1/50000

Roads and Paths, line feature class for E14c46 area
scale 1/50000

Bodies of water, rivers (line feature class) sea, and lakes
(polygon feature class) for E14c46 area, scale 1/50000

Soils and dense vegetation, polygon feature class
for E14c46 area, scale 1/50000
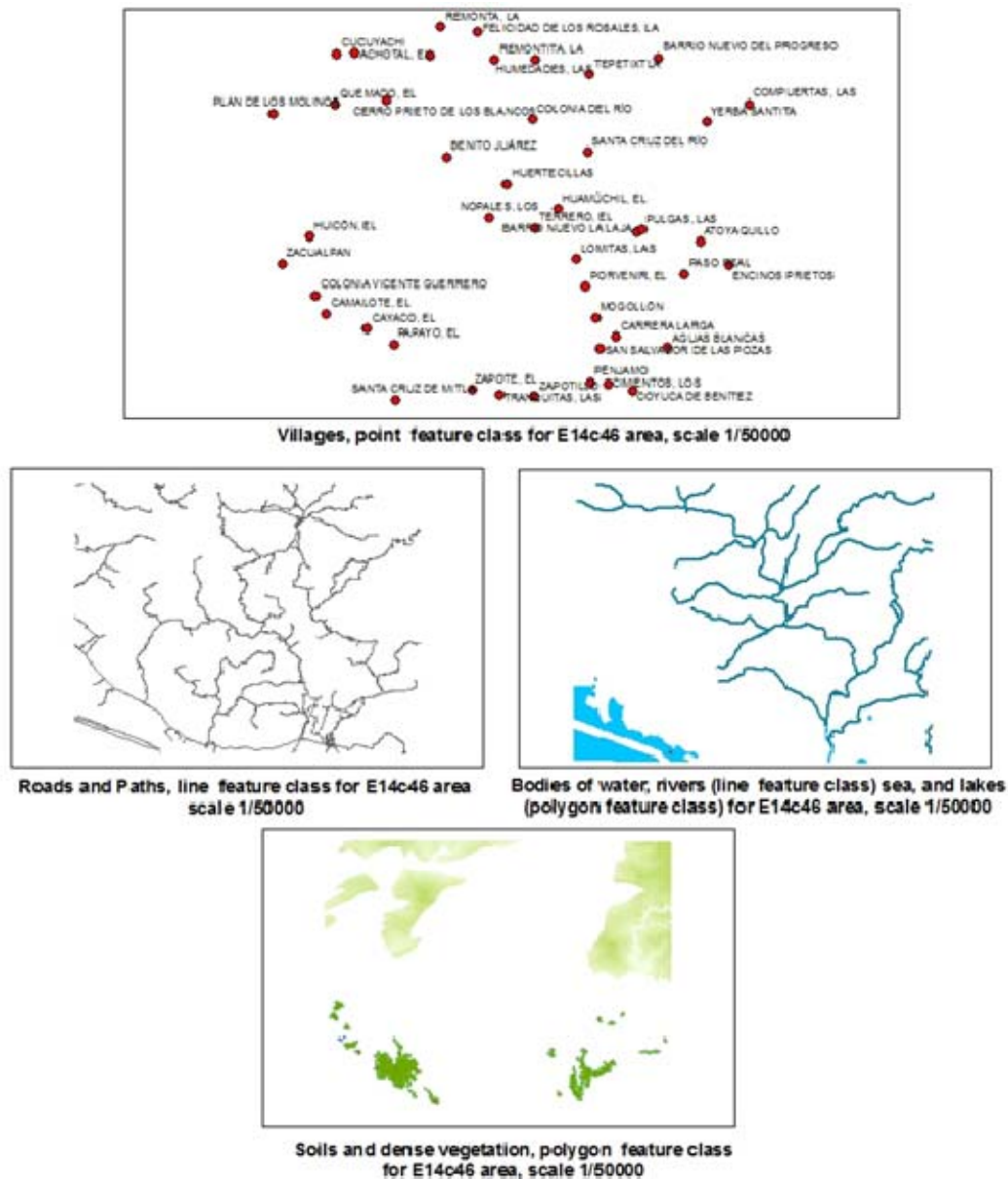
Figure 55.   Digital Information Products collected and forming the "raw dataset" into the GIS (Part 2/2)

Imagery activity

Collect required information products: N/A. (No imagery available)

Prepare information products: N/A.

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Export information products: N/A.

Import information products: N/A. (No imagery available)
Build raw dataset: N/A.

3.   Processing and Exploitation

Geospatial analysis activity

Put raw dataset into GIS: The "raw dataset" collected in the last step is uploaded into the GIS so it may allow the subsequent processing tasks. In this step, the GEOINT analyst creates a point feature class containing the location of the recon patrol to be rescued (Objective) as well as another with the four enemy observation points (En_Obs).[154]

Process data: In this step, the information products are set in the same coordinated system, so they can be easily managed and combined into the same ArcGIS map file. In addition, a mosaic formed by the maps of the surroundings of the area of interest is created, Figure 56.[155]

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[154] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 2** on p. **190** for further details on the geospatial analysis operations developed at this stage.

[155] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 3 and 4** on p. **190** for further details on the geospatial analysis operations developed at this stage.
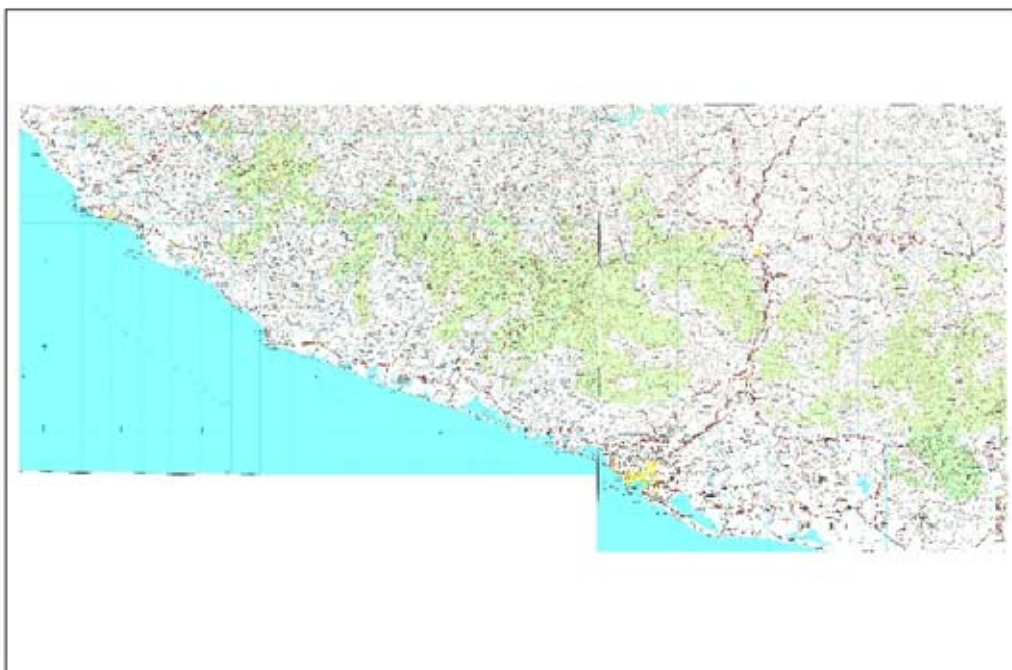
Figure 56.   Mosaic built by clipping the digital maps

In addition, in this part of the process the topographic features are rearranged with symbols and colors according to the attributes to be used in the Analysis and Production step of the GEOINT process. Figure 57, for example, illustrates how the Roads and Paths feature class are symbolized according to the types of roads.
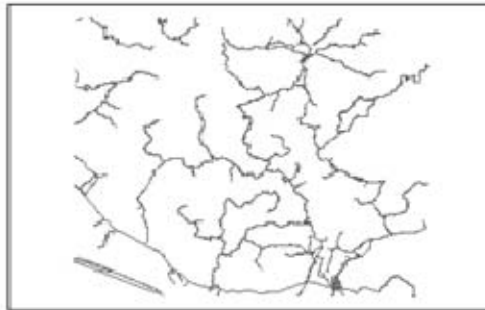
Roads and Paths, line feature class for E14c46 area
scale 1/50000 (RAW DATA SET)
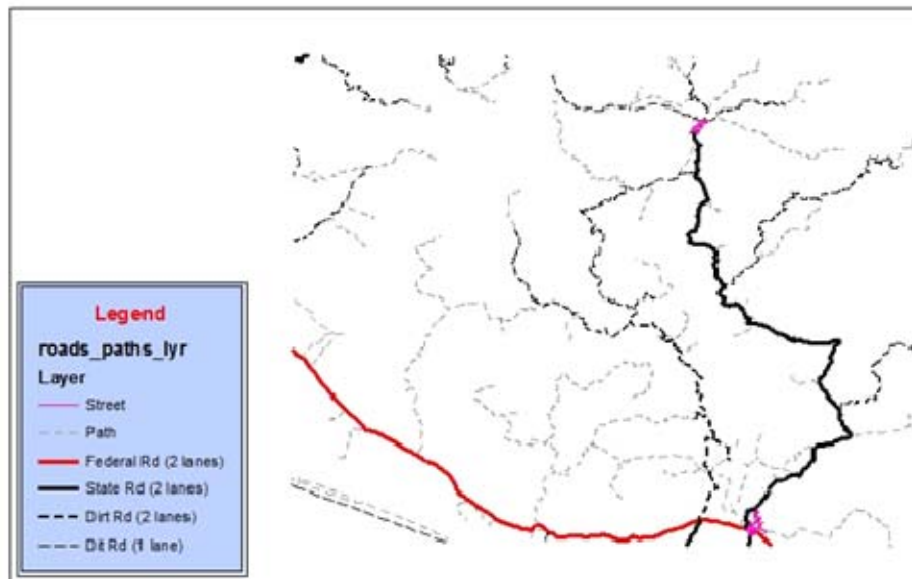
Roads and Paths, line feature class for E14c46 area
scale 1/50000 (PROCESSED DATA SET)

**Figure 57.   Raw (above) and processed (Below) roads and paths feature
class of the area of interest.**

Build ready-to-use GIS database: Once having processed all the data
that the analysts may use, it is organized in a GIS database (see footnote 54).

IMINT activity

Put raw dataset into GIS: N/A (No imagery available)

Process data: N/A

Image interpretation: N/A

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Build ready-to-use GIS database: N/A

4.   Analysis and Production

Integration of IMINT and geospatial analysis: N/A (No imagery available)

Develop analysis: A basis for overlaying the digital-information-products, the GEOINT analyst creates a hillshade (modified-Swiss-style)., This representation of the area offers a very realistic view of the surface because it gives a sense of depth to the viewer,[156] Figure 58.

Modified-Swiss-Style Hillshade
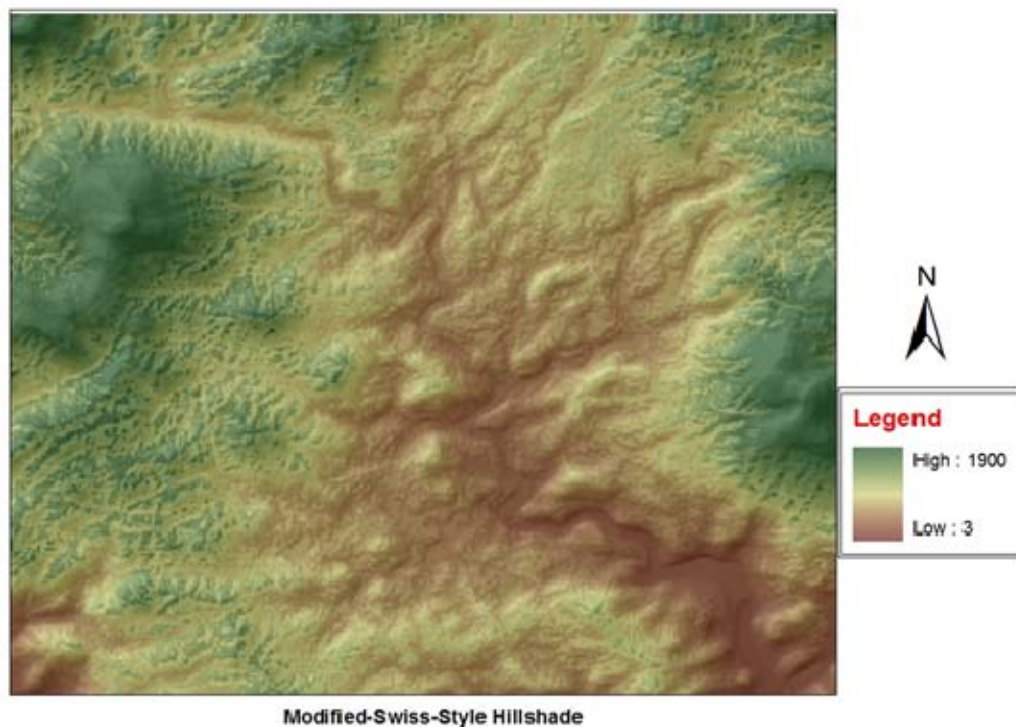
Figure 58.   Hillshade of the area of interest to be used as a basis for the geospatial analysis

The next step is to input the features required over the created surface in such a way that the decision makers can quality COP. Some of these tasks

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[156] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 5** on p. **192** for further details on the geospatial analysis operations developed at this stage.

involve the buffering of the demilitarized zone on the ground as well as the demilitarized-fly-over-zone from the given geographic position. This is illustrated in the next step.[157]

      Produce GEOINT: The next task is to produce the GEOINT needed by the decision-makers. This is done by generating a clear COP, which is the final product to support the Commander's decision. The first part of the COP, Figure 59, is a map of the area with the most important topographic features, which offers a sense of depth to the viewer because of the modified-Swiss-style-hillshade as well as the use of simbology and colors. In this way, the decision makers can discern one feature from another when studying it. The second map, Figure 60, is another map product that provides visualization of the surroundings of the area of operations in a minor scale so the decision makers can locate it regionally. The third part is a GEOINT map, Figure 61, which represents some of the intelligence provided by the High Command. The fourth and final part is the 3D representation of the area, which could be displayed in a video clip or interactively in ArcGIS, Figure 62 and Figure 63.

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[157] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 6** on p. **195** for further details on the geospatial analysis operations developed at this stage.

COYUCA DE BENITEZ MAP 1/50000

Legend

HABITAN
- 102 - 305
- 306 - 640
- 641 - 1245
- 1246 - 3951
- 3952 - 11364

— Street
— Path
— Federal Rd (2 lanes)
— State Rd (2 lanes)
--- Dirt Rd (2 lanes)
--- Dit Rd (1 lane)
— Rivers
Cultivation
Subject to Flooding
Land
Sea and Lakes
High : 1900
Low : 3
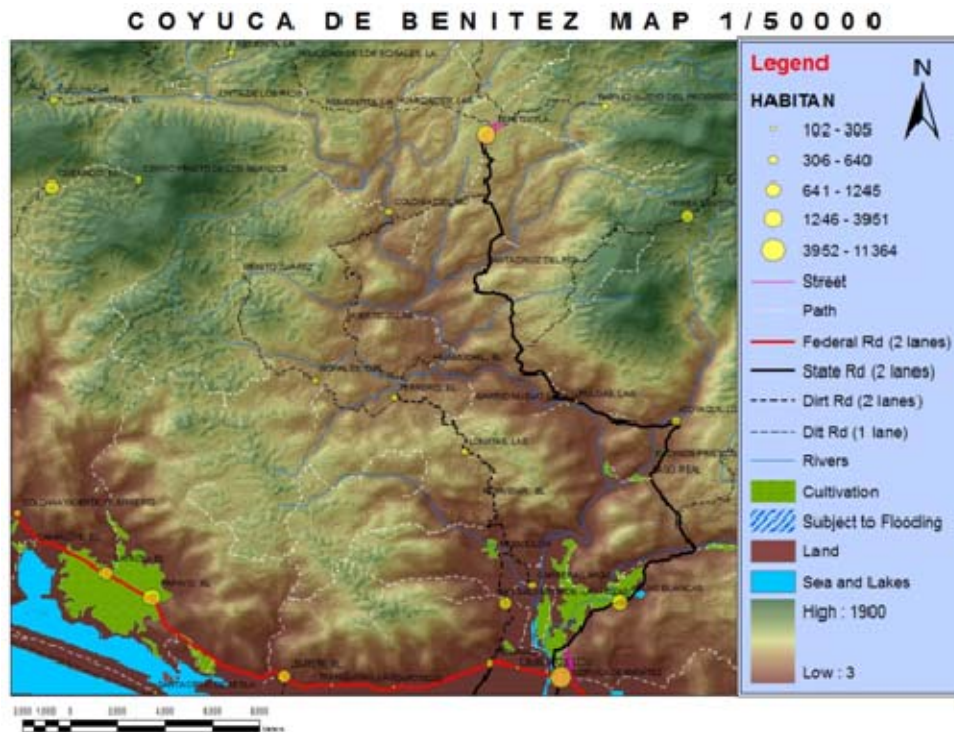
Figure 59.   First part of the COP: area of interest with topographic features

Coyuca de Benitez and Surroundings

Scale
1:342,857

Coyuca Area

ACAPULCO
Navy Zone

Figure 60.   Second part of the COP: area of operations and surroundings

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GEOINT MAP; AREA OF OPERATIONS
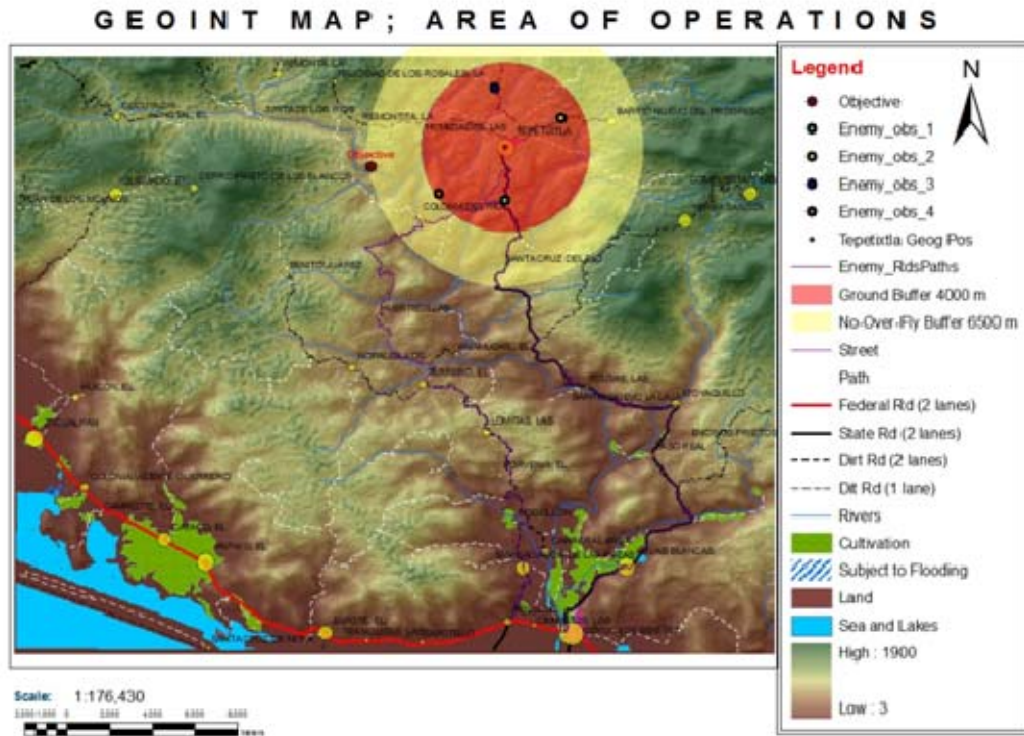
Figure 61.   Third part of the COP: GEOINT map
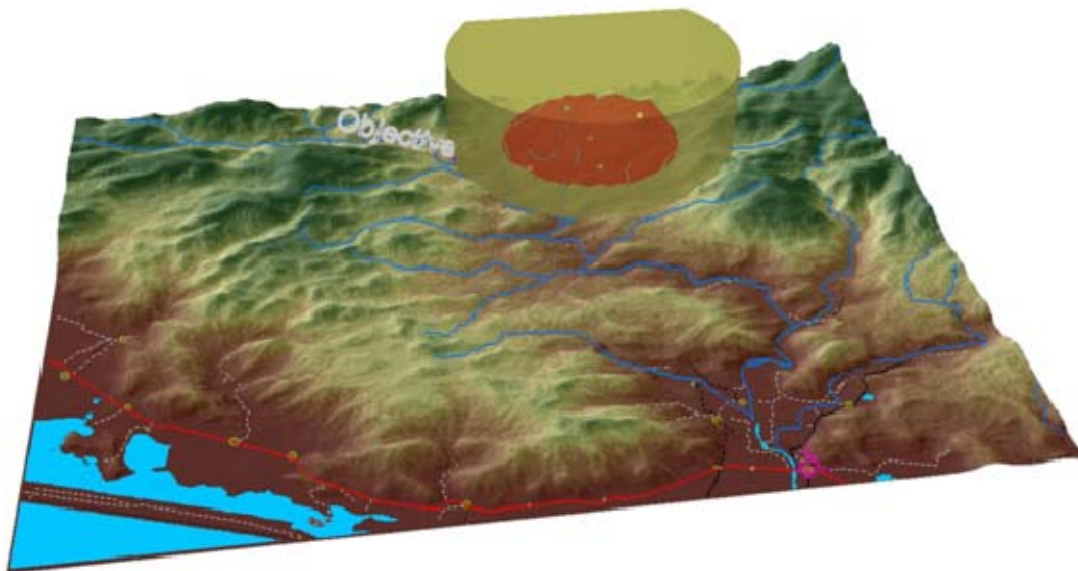
Figure 62.   Fourth part of the COP: 3D representation (1)
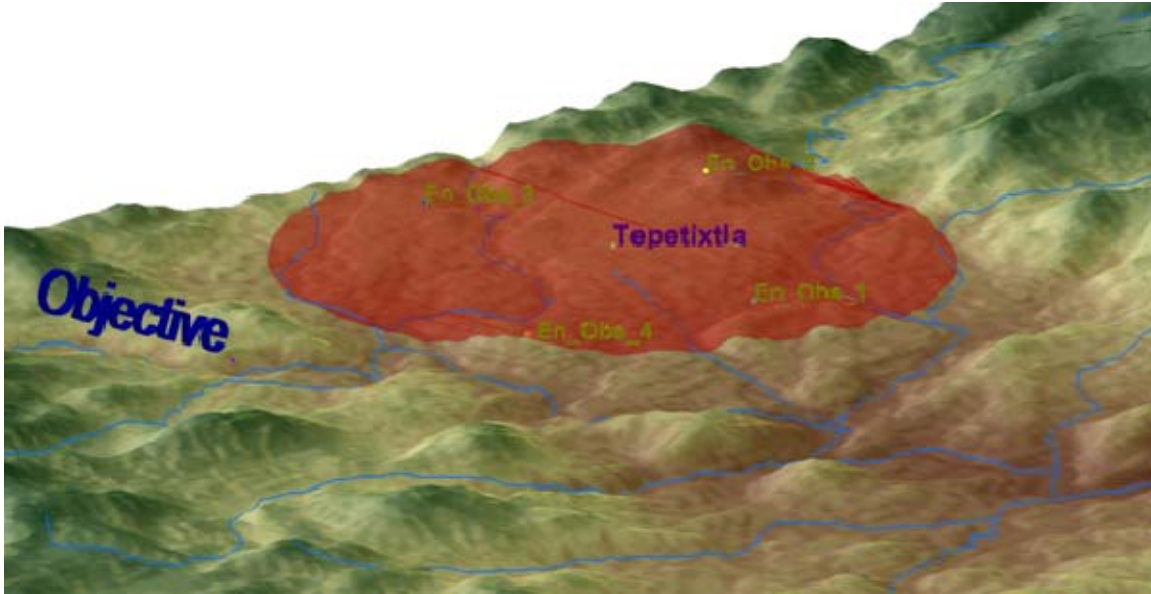
Figure 63.   Fourth part of the COP: 3D representation (2)

Prepare GEOINT for dissemination: The GEOINT could be prepared in many different ways, but it would depend on consumer preferences; in this case, the final product could be delivered in paper maps and graphics, in PowerPoint presentations, or directly displaying the ArcGIS (2D) and ArcScene (3D) digital maps during the briefing. In the specific case of the 3D maps, they could be presented in a video-clip as well.

5.   Dissemination

Present GEOINT to the consumers (decision-makers): The GEOINT is presented to the Pacific Navy Force Commander and his Staff.

6.   Evaluation and Feedback

Evaluate results in every task: As stated before "Evaluation and Feedback" is a quality-control-mechanism, and in this scenario it may have been developed during the entire GEOINT process.

Receive feedback from the decision-makers and other analysts: It could be assumed that the feedback received pointed to some map variations

during the dissemination briefing. ArcGIS allows for interactivity (on the fly) so the decision makers do not have to wait for another GEOINT dissemination meeting.

Determine what can be improved: Done.

Go back to previous steps if necessary: Done.

In this first GEOINT cycle, every step of the GEOINT-process-model was identified in order to provide the reader with a guide of how the model is applied in practice. It is worth recalling that the GEOINT-process' steps could be developed "on the fly" by GEOINT analysts, as well as the fact that the model provides the analyst with the flexibility of going back to previous steps when required, in order to ensure effective workflow.

The flexibility in the workflow, as well as the importance of maintaining a constant evaluation of the results and receiving feedback from the consumers, will be represented in the next GEOINT cycle. In similar cases to the present scenario, which can be considered as a sensitive case due to the risk involved and the operational and political implications, constant feedback from the consumers (operational commanders) is required to ensure the workflow and effective results so they may fulfill their expectations.

In order to illustrate better the practical workflow of this GEOINT process, the following GEOINT cycle will only indentify the specific steps applicable.

D.   GEOINT PROCESS (SECOND CYCLE)

Once the Commander of the Pacific Navy Force has received the GEOINT disseminated in the previous cycle, he meets with his Staff and subordinate Commanders; they decide to insert a SOF unit by aerial infiltration (free-fall parachuting) as near as possible to the objective. This SOF unit may provide first aid to the injured soldiers and evacuate them in a pre-designed extraction where the rescue force and the recon patrol may be extracted by two Navy helicopters.

The rescue force may be projected from a Navy ship that may be located in coordinates UTM 17Q 361674.543688 _ 1880404.58747 and that ship also may receive the rescue force and recon patrol at the end of the operation.

The Navy Force Commander designates the SOF commander as the leader of the rescue operation and briefs him about the constraints established by the High Command. In addition, the SOF commander is ordered to provide his GEOINT requirements for the operation's planning.

1.   Planning and Direction

Because the operation may be executed as soon as possible, the SOF commander coordinates with the GEOINT analysts, and they decide that he will be involved in the execution of the GEOINT process. That is in order to ensure the flow of the cycle and to make last minute changes, if required, as well as to provide timely feedback to the analysts.

Hence, the SOF commander decides to do the infiltration at night to ensure the secrecy of the initial phase of the operation so he first asks the GEOINT analyst for a suitability map for a drop zone and related risk maps considering the following criteria:

e. Near to the objective.
f. Minimum distance from the border of the 4000 m ground buffer: 1000 m.
g. Outside of the maximum fire range of the PUO weapons from the paths they use and their observation points.
h. Outside of the sight of the four enemy observation points; with a minimum of 200 m from their viewsheds.
i. Minimum distance from power lines: 500 m.
j. Minimum Slope: 5°.
k. Minimum distance from dense vegetation: 100 m.
l. Minimum distance from the sea and lakes: 500 m.
m. Minimum distance from rivers: 100 m.
n. Minimum distance from cultivation areas: 100 m.
o. Minimum distance from villages: 100 m.

Define the problem: The problem for the GEOINT analyst is to develop suitability maps for potential drop zones in the area of operations by considering the risks and other factors given by the criteria previously established by the SOF commander.

Define GIS criteria: to do the geospatial analysis, the GEOINT analyst will require the GEOINT and datasets from the previous cycle of this scenario and a map containing the power lines, which can be assumed to be in hands of the analyst as well.[158] Details APPENDIX A section 7

2.   Collection

N/A (It was done in the first cycle)

3.   Processing and Exploitation

N/A (It was done in the first cycle)

4.   Analysis and Production

Develop analysis and produce GEOINT[159]: To develop the analysis, first the GEOINT analyst divides the risks faced by the rescue force when landing in that area into two categories "Terrain and Accessibility" and "Enemy Threat." The first one embraces the risks related to the surface and other topographic features in the area and the second category embraces all of the threats posed by the enemy.

First Category: Terrain and Accessibility

ArcGIS is a very useful tool for visualization; consequently, simply overlaying the feature classes involved in the analysis can often provide an idea of the risks present in the area. However, if analysts only use ArcGIS's

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[158] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 7** on p. **195** for further details on the geospatial analysis operations developed at this stage.

[159] "Develop Analysis" and "Produce GEOINT" are two separated tasks in the GEOINT-process-model, but they can be merged when required, as in this specific case that requires illustrating to the reader the products obtained in every step.

visualization tools for GEOINT analysis, they waste ArcGIS's ability to develop complex analyses through its sophisticated algorithms that provide precise results, otherwise impossible to get. Nonetheless, ArcGIS needs inputs and those inputs must be adequate to the task. Hence, in this case the GEOINT analyst starts developing the risk analysis with the category of Terrain and Accessibility by doing basic math modeling operations.

The GEOINT produced in the category of Terrain and accessibility is illustrated in Figure 64.
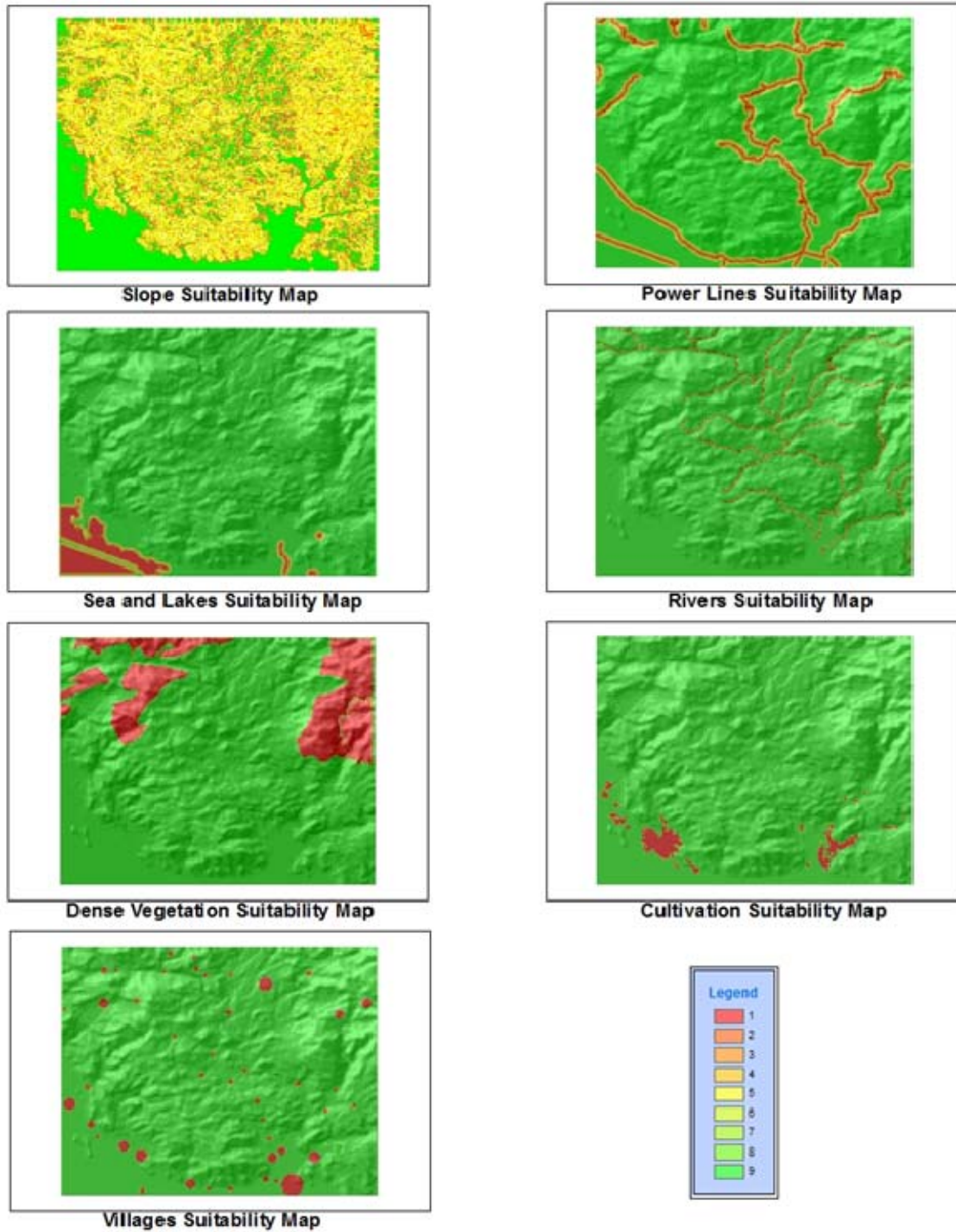
Figure 64.   Terrain and Access Risk Suitability Maps; 9 = Best (green), 1 = Worst (red)

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The suitability maps produced here represent the more risky, or less suitable, zones in red with a value of 1 and the less risky, or more suitable, zones in green with a value of 9. These values of suitability are based on the distances from the features that represent the threat, so in order to get these distances, the GEOINT analyst must introduce the parameters previously established, such as the risky distance to a feature for the landing of paratroopers or helicopters.[160]

Once having the Terrain and Access Suitability maps aforementioned, they are overlaid to get the Suitability map of the whole category. Figure 65 represents the overlaying of the different layers in this category and their assigned values (weights). In addition, Figure 66 is the suitability map that resulted from the overlaying.[161]

Coyuca; Terrain and Accessibility Weighted Overlaying

Slope 27%
Power Lines 32%
Sea and Lakes 10%
Rivers 10%
Dense Vegetation 9%
Cultivation 4%
Villages 8%
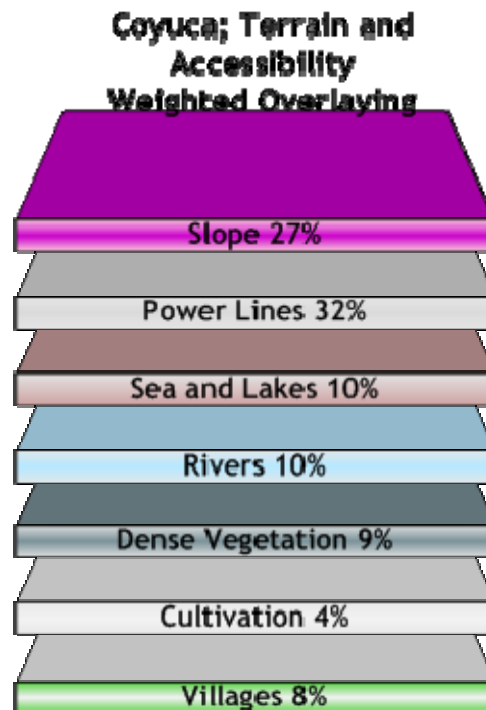
Figure 65.   Representation of the Terrain and Accessibility weighted overlaying with weight values assigned

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[160] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 8** on p. 196 for further details on the geospatial analysis operations developed at this stage.

[161] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 9** on p. 206 for further details on the geospatial analysis operations developed at this stage.
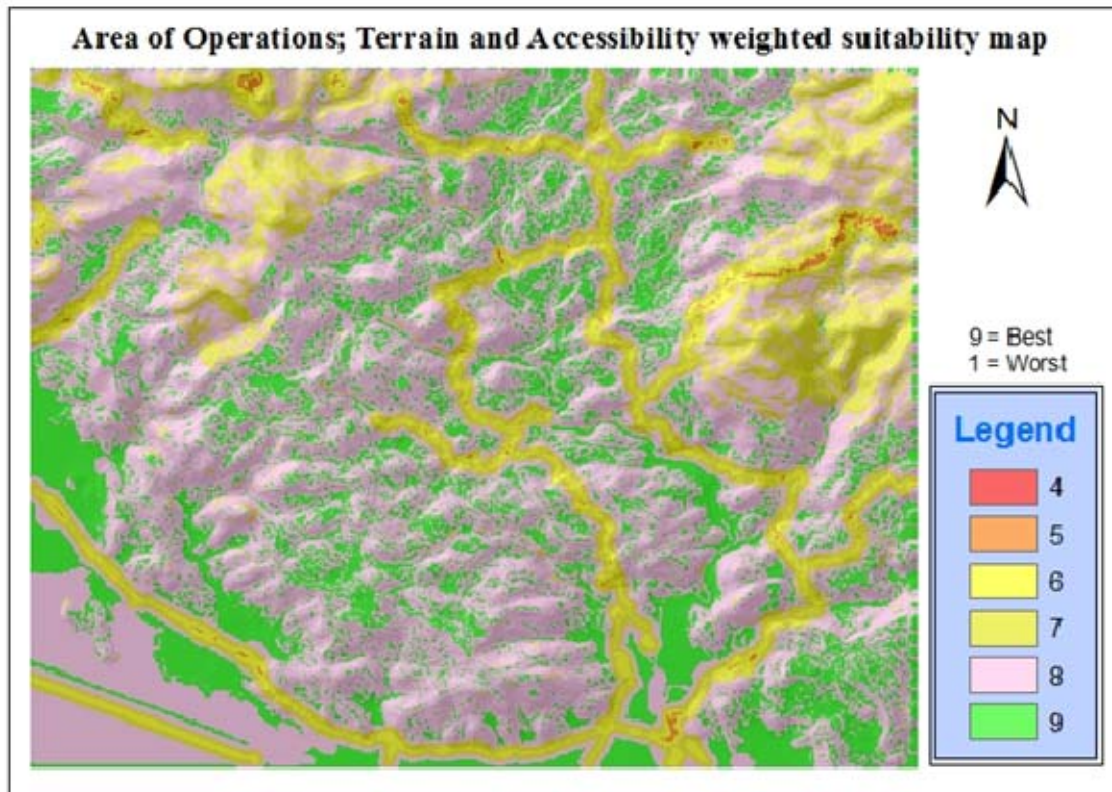
Figure 66. Terrain and accessibility weighted suitability map; the green areas represent potential Drop Zones (so far)

The weighted suitability map obtained is a GEOINT product that illustrates the risky areas and the potential drop zones regarding to terrain and accessibility features; however, it is still necessary to consider another factor such as enemy threat, which is the next category to be mapped.

Second Category: Enemy Threat

In all of the layers of this category, the minimum distance to features is the factor used to calculate risk; as such, the same process developed for the Terrain and accessibility layers applies in this case. Exception is made with the slope layer, which instead of distance takes into account the degree of slope in every area. However, the only feature that the GEOINT analyst does not count on is the enemy-observation-points' viewshed. The viewshed map is attained by

executing the Spatial Analyst> Surface> Viewshed tool to each observation point. If the analyst were to input a feature with the four observation points, the result would be a raster with the whole viewshed of the four points together. However, in this case, they are taken separately so that they can be analyzed one by one when necessary. The result from the viewshed operation for every point is a two-color raster dataset, one color representing the visible areas and the other one representing the non-visible areas from the observation point. Once having the viewsheds, the GEOINT analyst sets the color representing the non-visible areas as null values so that the resulting rasters illustrate only the visible areas from the observation points. This tool also considers the curvature of the earth surface (if selected) and elevations that limit the visibility from a given point in its surface, Figure 67.
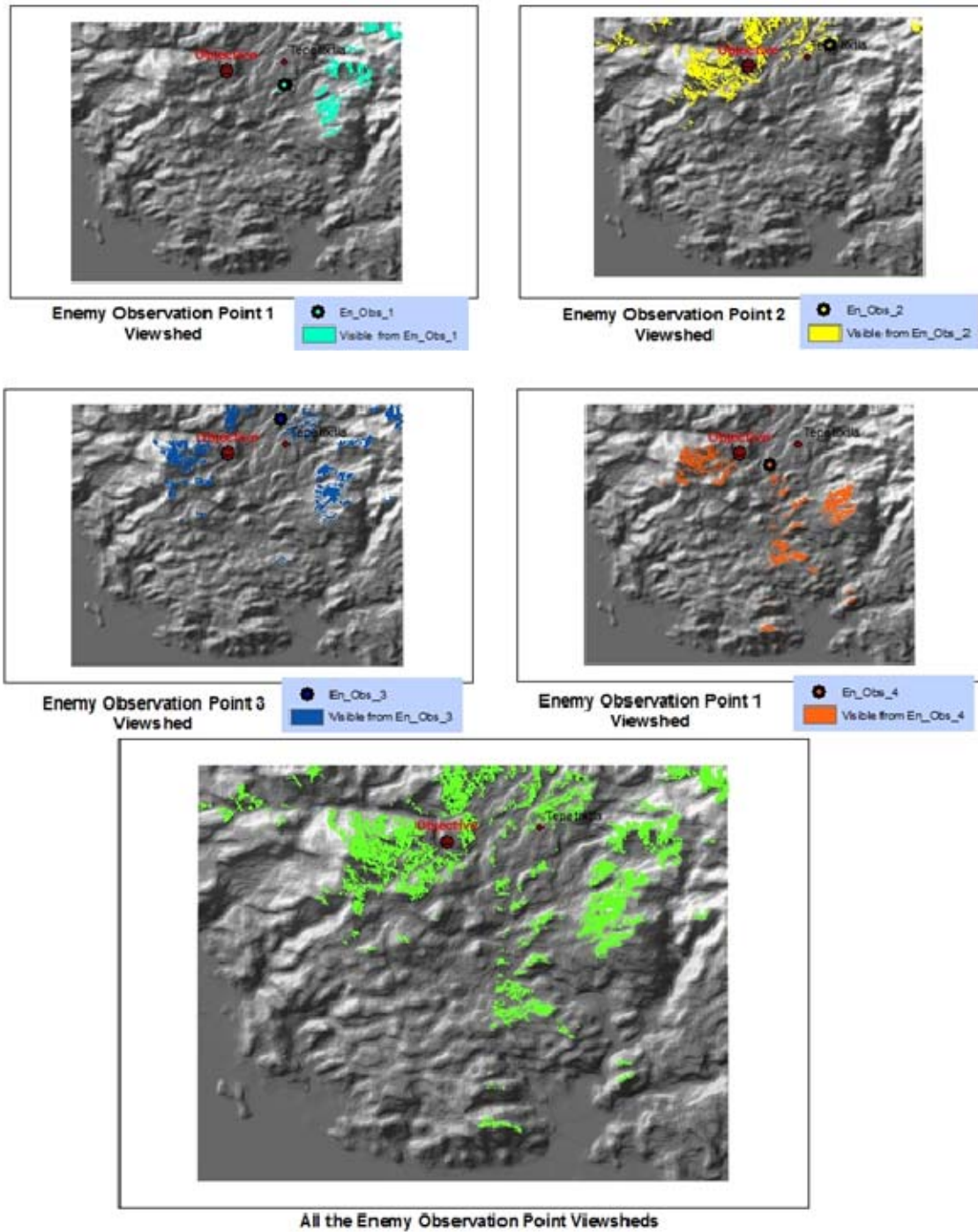
Figure 67. Enemy observation points viewsheds related to Tepetixtla and the Objective's location

Once having the enemy viewshed, the GEOINT analyst counts on the required layers to run the distance tools in order to get their respective suitability maps. Hence, in order to get the required maps the GEOINT analyst must introduce the parameters previously established such as the risky distance to the enemy's viewshed or to the range of an enemy's weapon. The GEOINT produced in the category of Enemy Threat is illustrated in Figure 68.[162]

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[162] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 10** on p. **207** for further details on the geospatial analysis operations developed at this stage.

Ground Demilitarized Zone Suitability Map

Enemy Obs Points Fire Range Suitability Map

Enemy Obs Point 1 Viewshed Suitability Map

Enemy Obs Point 2 Viewshed Suitability Map

Enemy Obs Point 3 Viewshed Suitability Map

Enemy Obs Point 4 Viewshed Suitability Map

Enemy Roads and Paths Fire Range Suitability Map

Legend
1
2
3
4
5
6
7
8
9
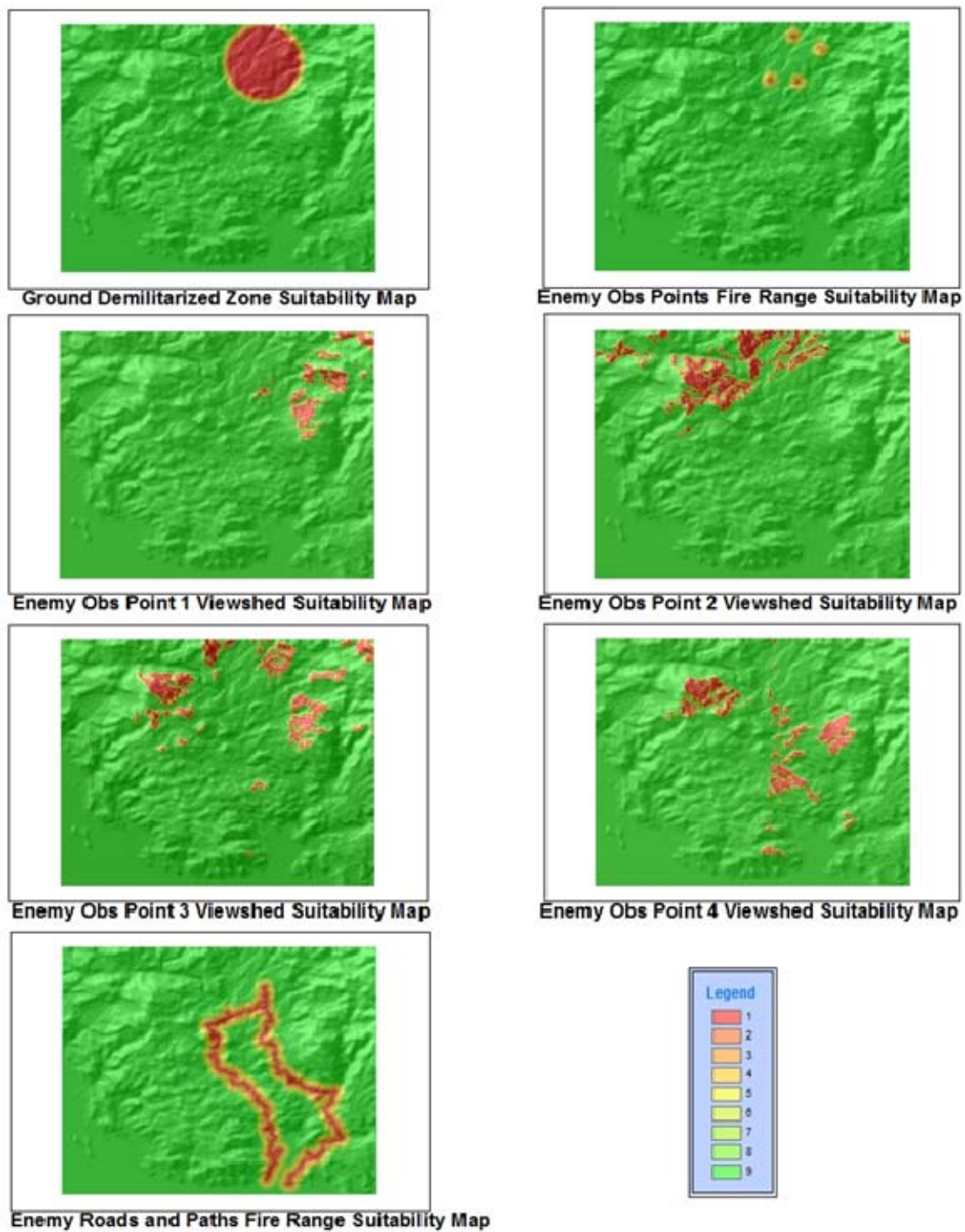
Figure 68.   Enemy Threat Suitability Maps: 9 = Best (green), 1 = Worst (red)

As in the case of the other category, once having the Enemy Threat Suitability maps, the Weighted Overlay tool is used to combine the layers in order to get the Suitability map of the whole category. The assigned values and the layers in regard of the enemy threat are presented in Figure 69.
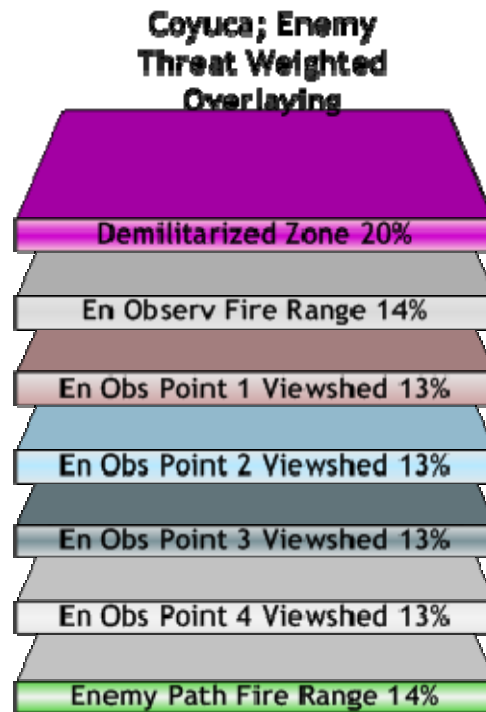
Figure 69.   Representation of the Enemy Threat weighted overlaying with weight values assigned

Once having these weights, the Weighted Overlay tool is executed: the inputs were the seven suitability layers of the Enemy Threat category, the weights in percentage, and the chosen reclassification is from 1 to 9 by 1. The output of this operation is the weighted suitability map for the Enemy Threat category and is illustrated in Figure 70.
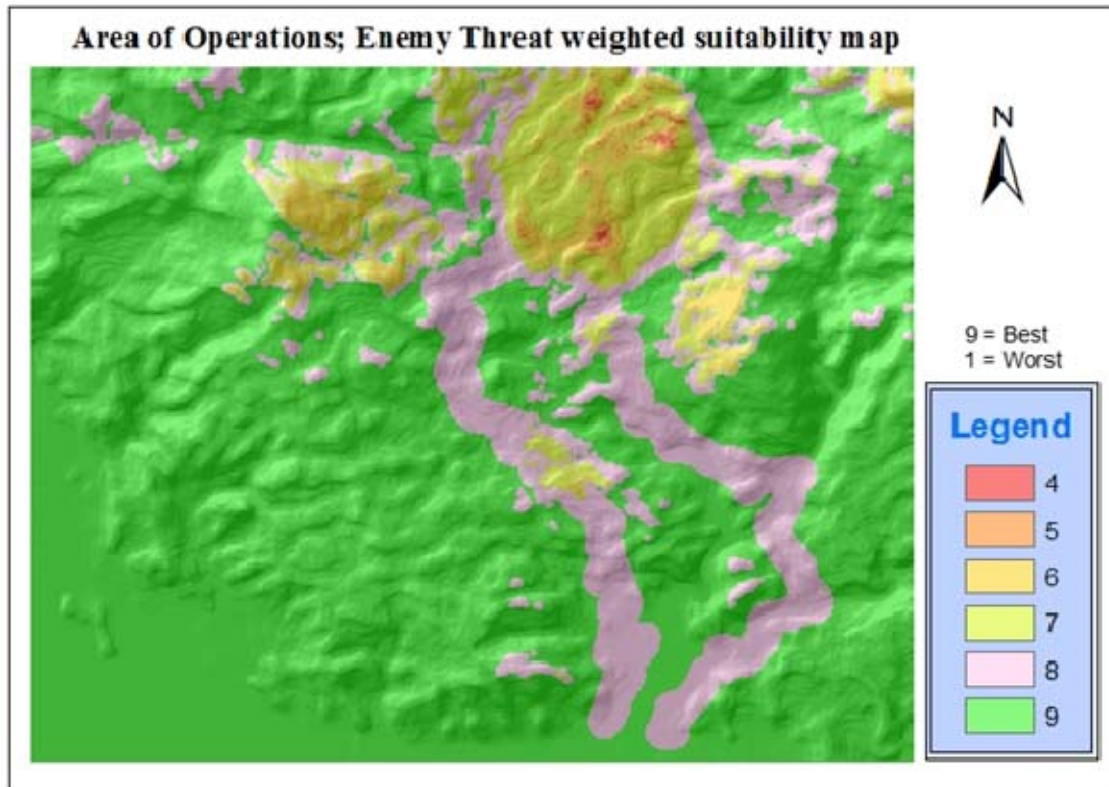
Figure 70.   Enemy Threat weighted suitability map

From the previous multiple layers that represented the various factors involved to obtain the suitable drop zones for the rescue forces, there are now just two that represent the categories into which the factors were divided. The next step is to overlay those two suitability layers, and the result is a map that represents the Total Suitability for drop zones in the area of operations, which is illustrated in Figure 71.
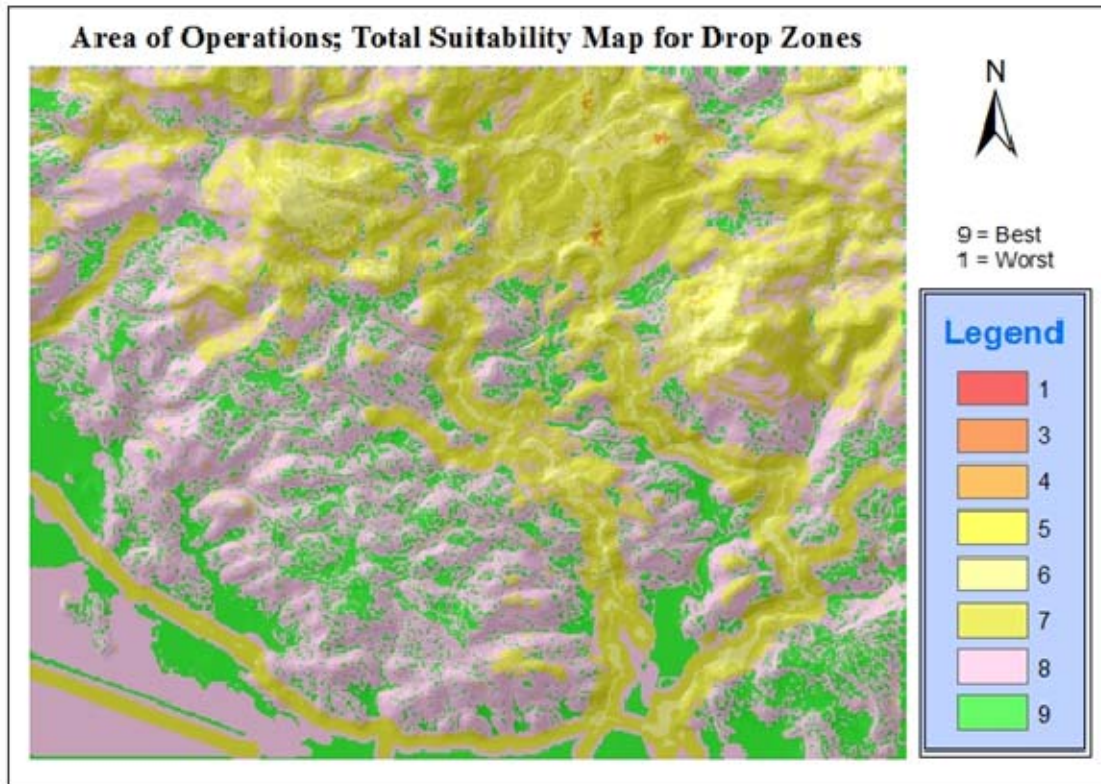
Figure 71.   Coyuca: Total Suitability Map for Drop Zones

Next, the SOF commander analyzes the GEOINT product and asks the GEOINT analyst to limit the potential drop zones according to the following parameters:

- The Drop Zone cells must have a value of 9 (best suitability value)
- Drop Zone minimum area must be 200 * 200 m = 40,000 m = 4 hectares
- Maximum distance from the objective must be 5,000 m

The GEOINT analyst executes the spatial analysis to delimit the zones as required by the SOF commander by means of the ArcGIS spatial analyst toolset. The output of this operation is a map with the best sites for drop zones meeting

the criteria established by the SOF commander. The results are represented in the GEOINT map illustrated in Figure 72.[163]
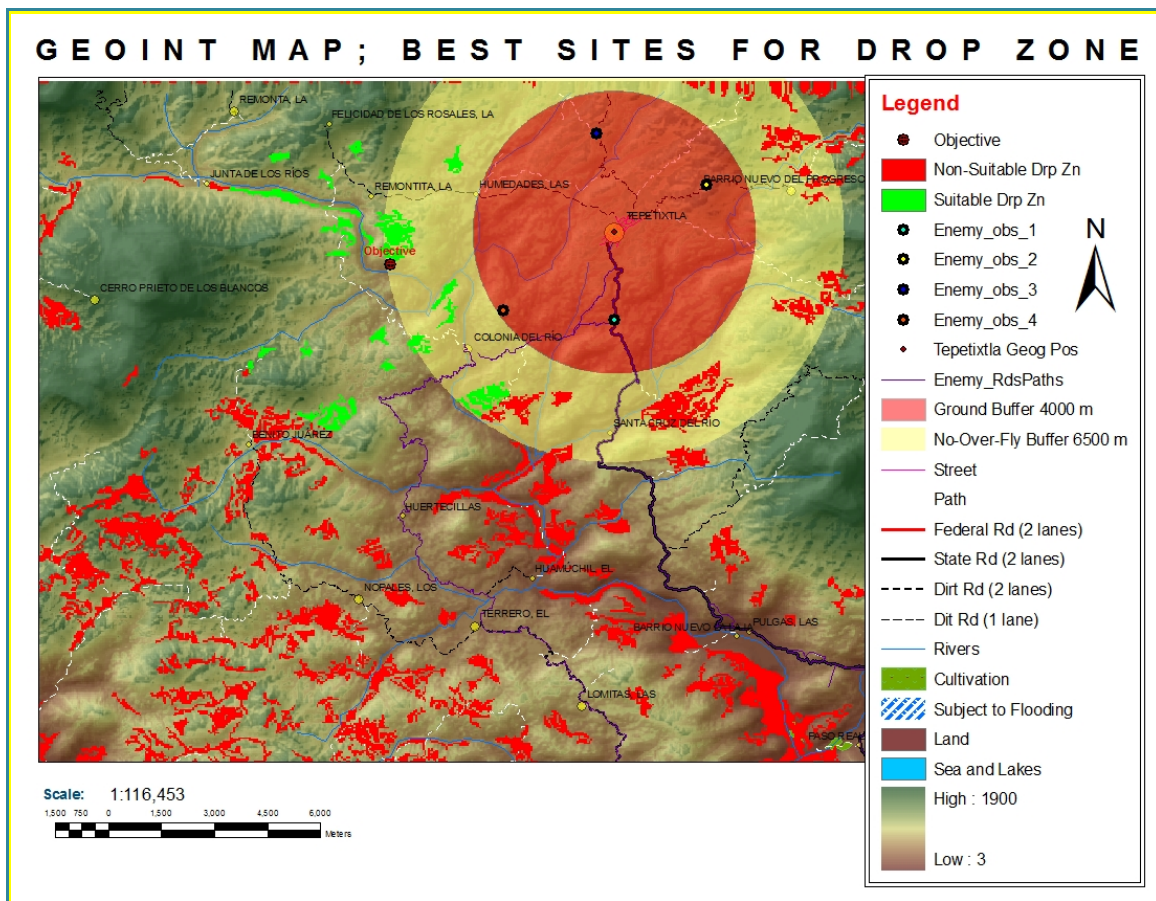
Figure 72. GEOINT map showing the best sites for drop zone (green) in the area of operations

The SOF commander then asks for a visualization of the area in 3D to get a better perspective of the nearest suitable drop zones. The map is presented to him in ArcScene, Figure 73.

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[163] Those with some knowledge in geospatial analysis can refer to **APPENDIX A section 11** on p. **211** for further details on the geospatial analysis operations developed at this stage.
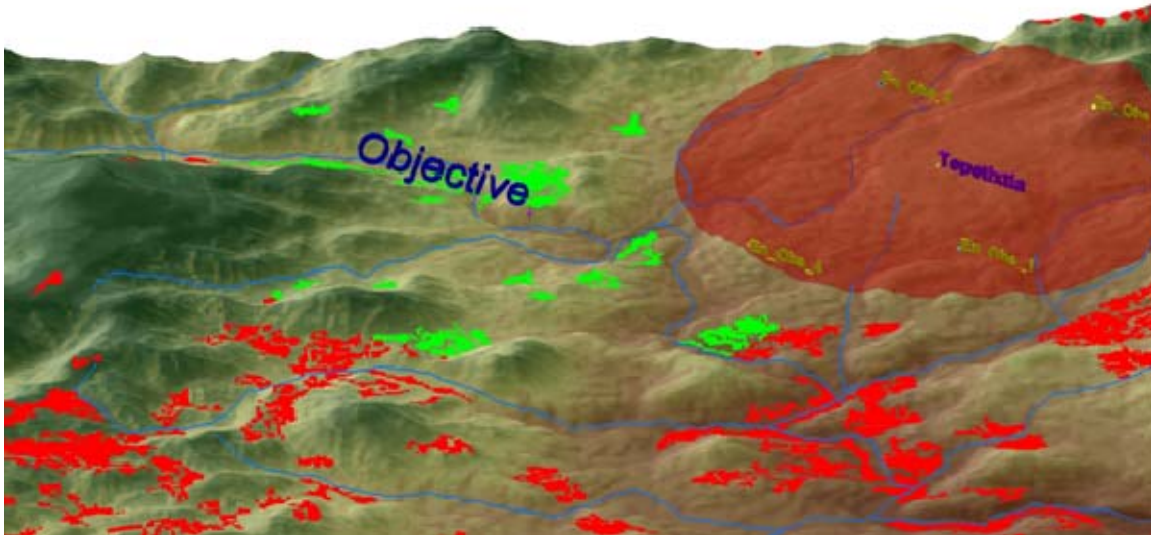
Figure 73.   3D Visualization of the best sites for drop zone with ArcScene

Once having studied the 2D and 3D GEOINT maps, the SOF commander makes a decision about the location of the drop zone, and the GEOINT analyst introduces the features that locate the drop zone area in the maps, Figure 74.
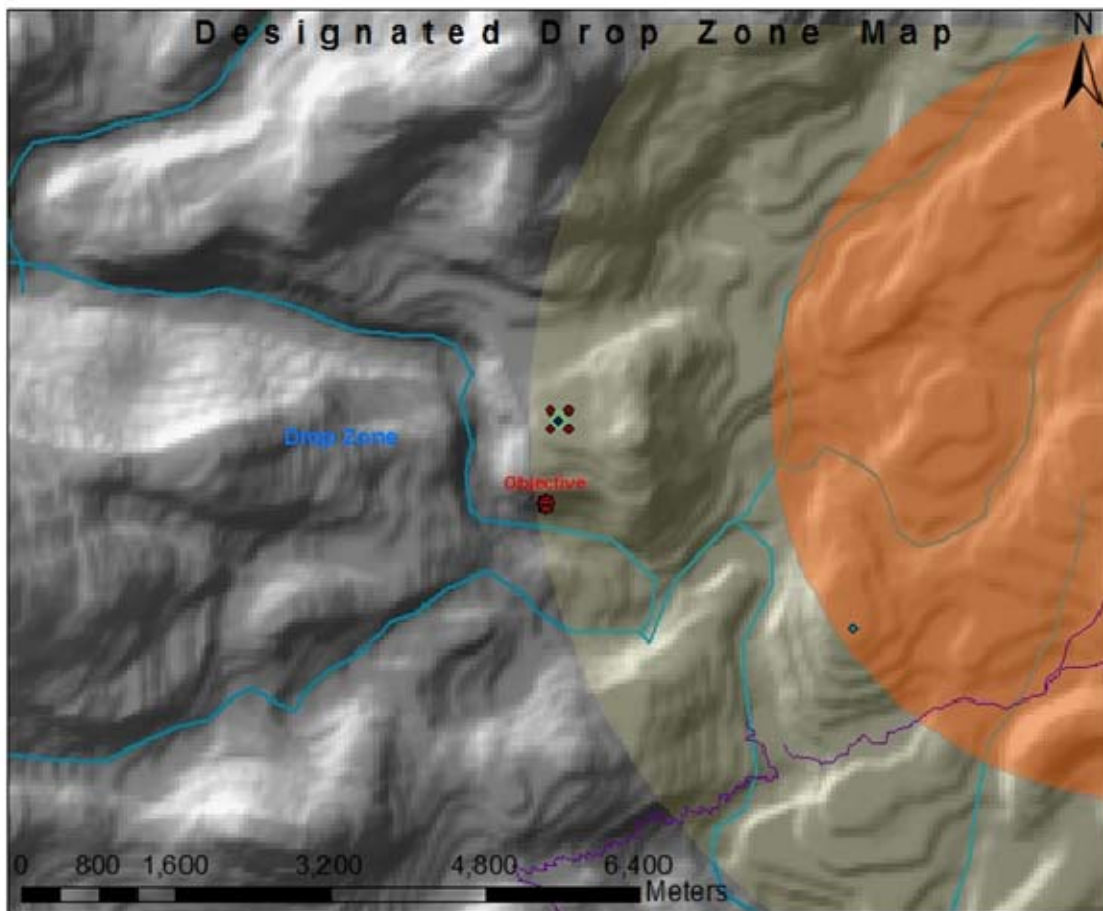
Figure 74.   GEOINT: Map showing the Designated Drop Zone

As an extra task in this scenario, the GEOINT analyst uses Model Builder tool, which allows the analyst to create a model formed by the different functions used to get a map, for example, the combination of functions developed to get a suitability map. The model that has been created is saved in an ArcGIS toolbox so that it becomes available to the analyst whenever it is required. These models may allow the analyst to input different variables in future geospatial operations to get results more quickly than having to develop a new map function by function. In addition, the analyst is able to share the models with other ArcGIS users. Hence those models will make the process of getting a map with the best sites for drop zones easier in the future for the analysts, as well as to provide

them with the capability of changing initial parameters and rapidly getting different results in maps or layers. This capability also may allow for the comparison of the resulting layers—one to the other in order to discover the influence of the input parameters over the outputs, according to the different values assigned. An illustration of one of the sub-models created for this analysis is in Figure 75, and it represents every operation executed earlier in this analysis to get the Terrain and accessibility suitability map.[164]

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[164] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 12** on p. **214** for further details on the geospatial analysis operations developed at this stage.
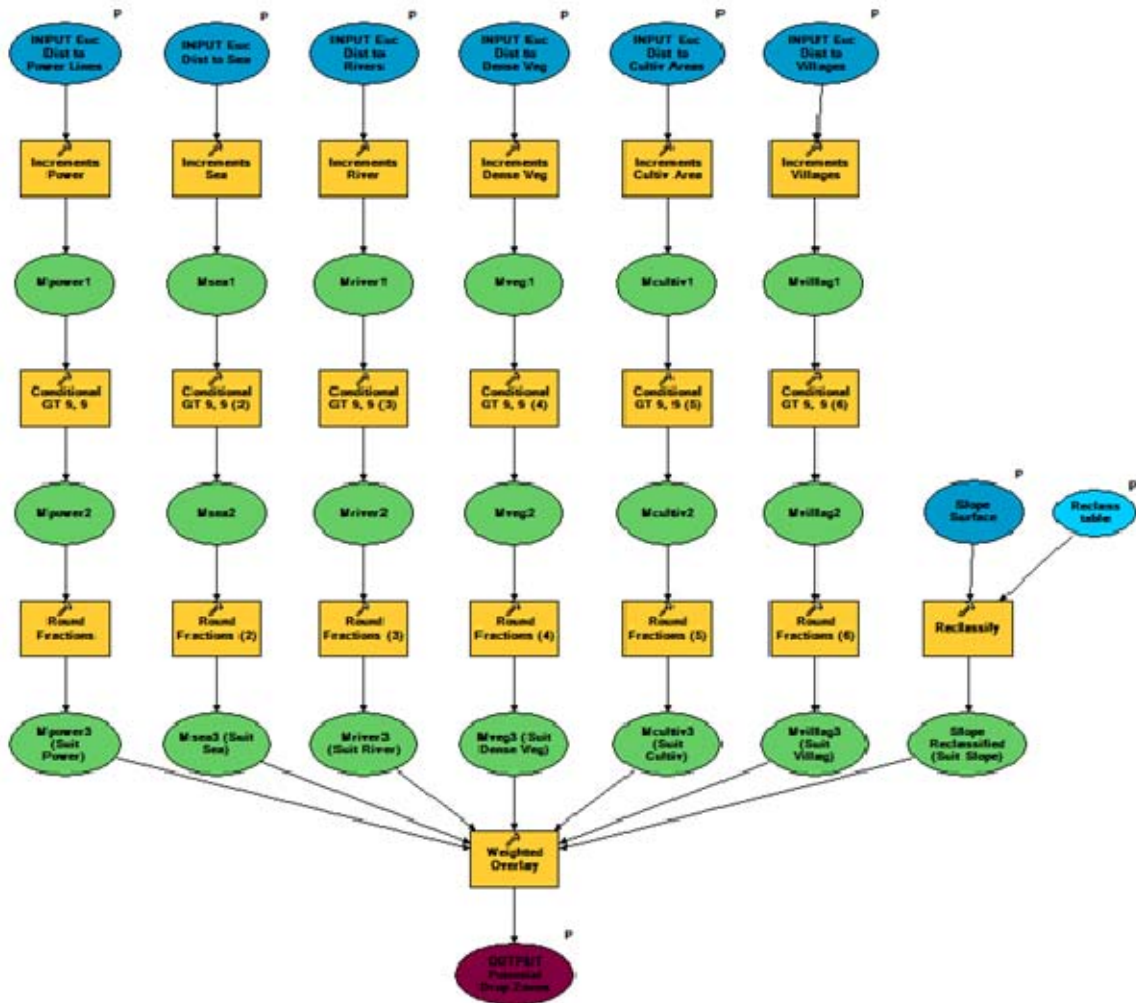
Figure 75. "1 DZ Terrain and Accessibility Sub-Model" graphic-representation

Because the Drop Zone selected by the SOF commander falls into the demilitarized-fly-over-zone (6,500 m buffer from Tepetixtla), it could not be used as a Helicopter Landing Zone (HLZ) for the extraction because this was one of the constraints given by the High Command. In addition, some parameters in that case are different values from the ones used to get the DZ. However the SOF commander, in coordination with the helicopters' pilots, decide to keep the

majority of the parameters taken previous to the DZ. Hence, the HLZ parameters, which may differ from the ones on the DZ, would be:

a.   The minimum slope may be 10°.

b.   The buffer to take into account in the Enemy Threat category may be the demilitarized-fly-over-zone (6,500 m) instead of the ground buffer.

c.   The minimum distance from the border of that buffer may be 200 m.

d.   HLZ minimum area: 100 * 50 m = 5,000 m. The GEOINT analyst considers a margin so he takes a 100 * 100 m area = 10,000 m = 1 hectare.

e.   Maximum distance from the objective may be 4,000 m.

Due to the similarities among the processes to get the DZ and the HLZ, the DZ sub-models can be used to get the HLZ just by changing the parameters that are different. However, the GEOINT analyst decides to create sub-models specifically to obtain the HLZ suitability maps for future use. This is done by just copying and pasting the DZ models and editing the names of the models and outputs, as well as changing the parameters. Figure 76 shows the toolbox with the four DZ sub-models and the four HLZ sub-models.
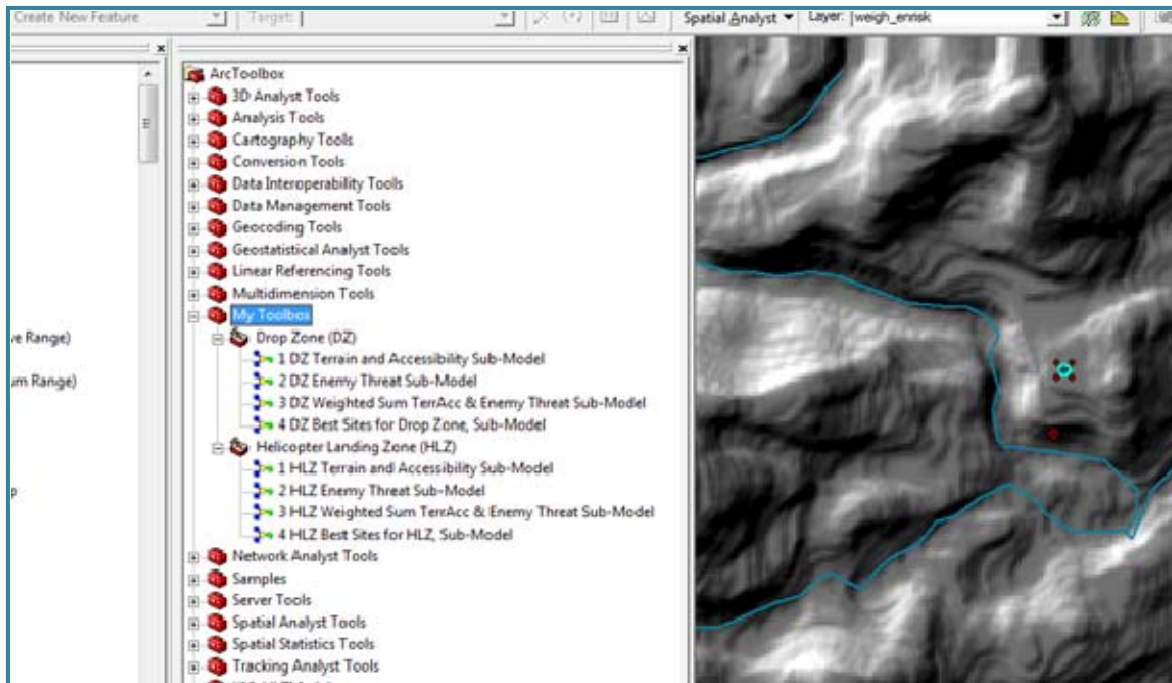
Figure 76. My Toolbox: GEOINT-analyst's personalized toolbox showing the DZ and HLZ Sub-models in the Arc Toolbox window

Once the whole HLZ model has been run, the GEOINT analyst obtains the Best Sites for the HLZ map, as illustrated in Figure 77, and it is shown to the SOF commander in 3D view to support his decision for designating the HLZ, Figure 78. Once he has designated the HLZ, it is input as a feature in the GIS, Figure 79.
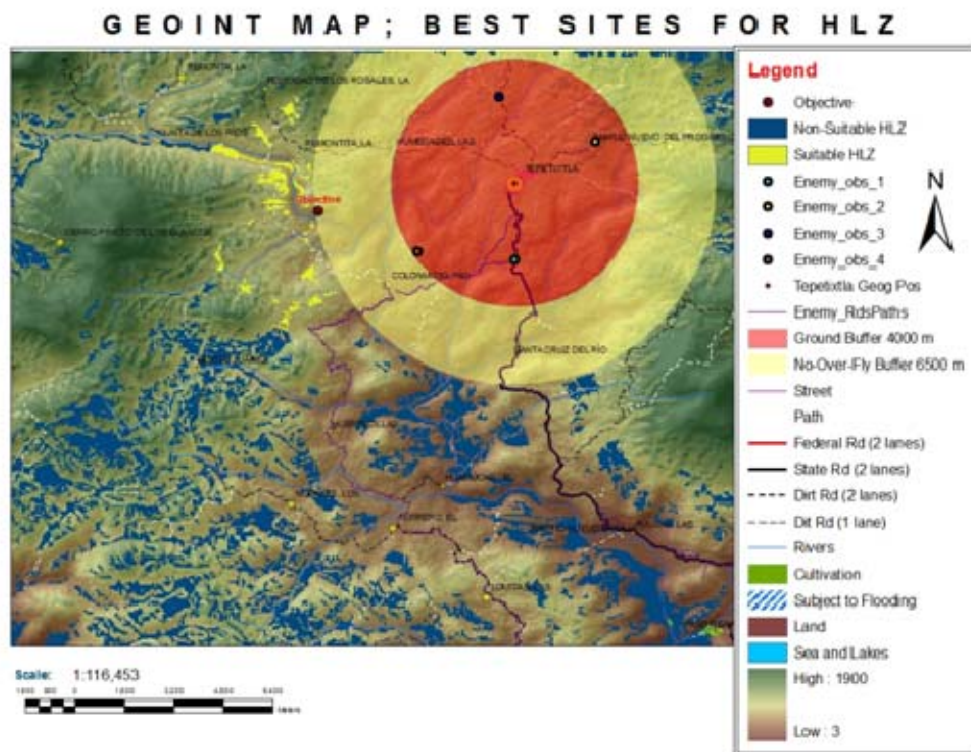
Figure 77. GEOINT map showing the best sites for Helicopter Landing Zone (yellow) in the area of operations
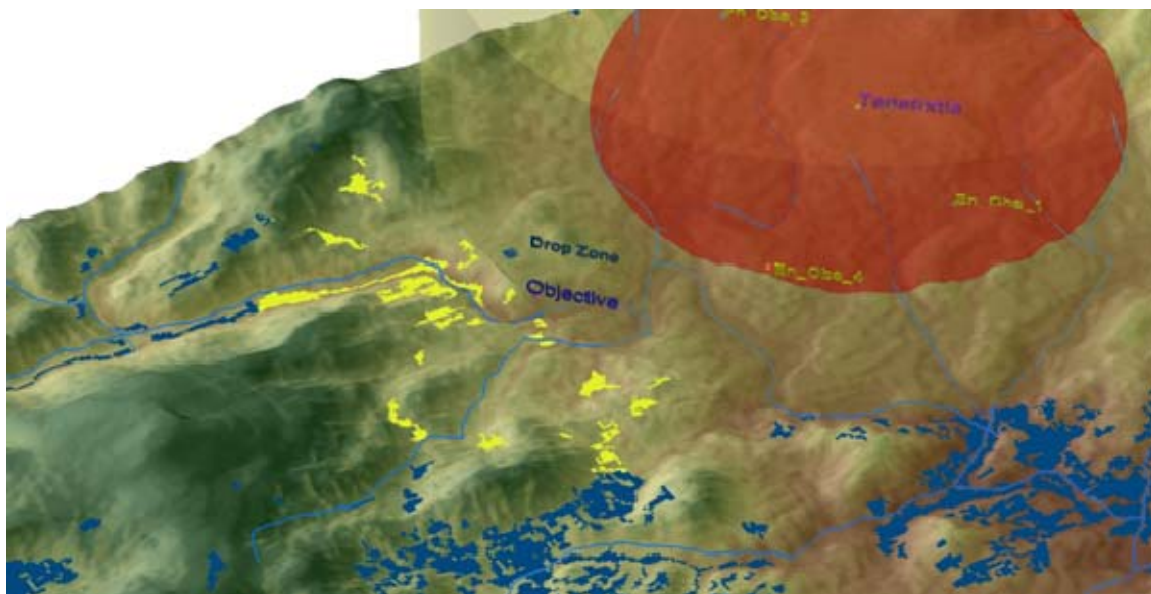
Figure 78. 3D perspective of the Best Sites for HLZ, note that the best sites for HLZ fall outside of the demilitarized-fly-over buffer (3D ring)
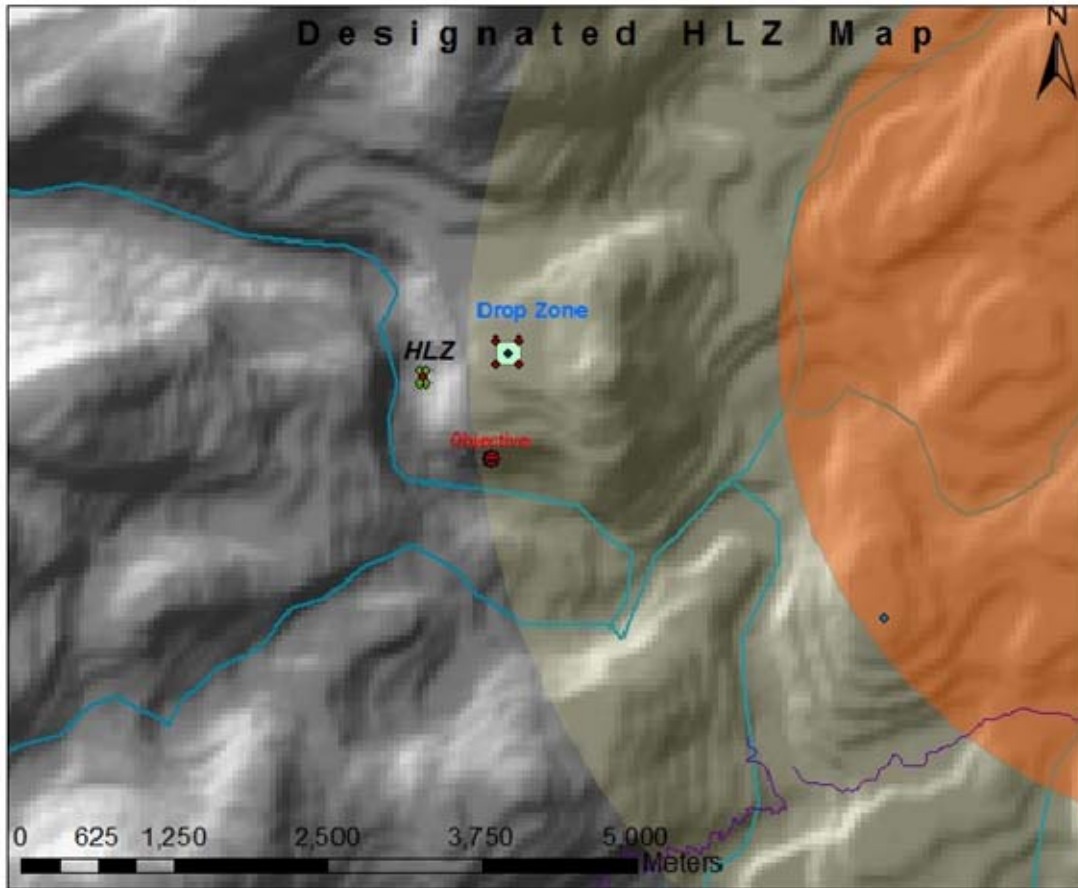
Figure 79.   GEOINT Map showing the designated HLZ

Next, the SOF commander asks the GEOINT analyst for the maximum elevation point in the mountain, where the DZ is located, in order to designate that as an observation and communications point. This is obtained by using the Military Analyst> Find Highest Point tool. With this tool, the GEOINT analyst draws a square in the area of interest and creates a point feature class with the highest point, Figure 80. Once done, the analyst adds the geographic position to the feature by running the Data Management> Features> Add XY Coordinates tool, and the coordinates are then added to the attribute table of that layer. Next, the GEOINT analyst is required to map the observation point viewshed, Figure 81.
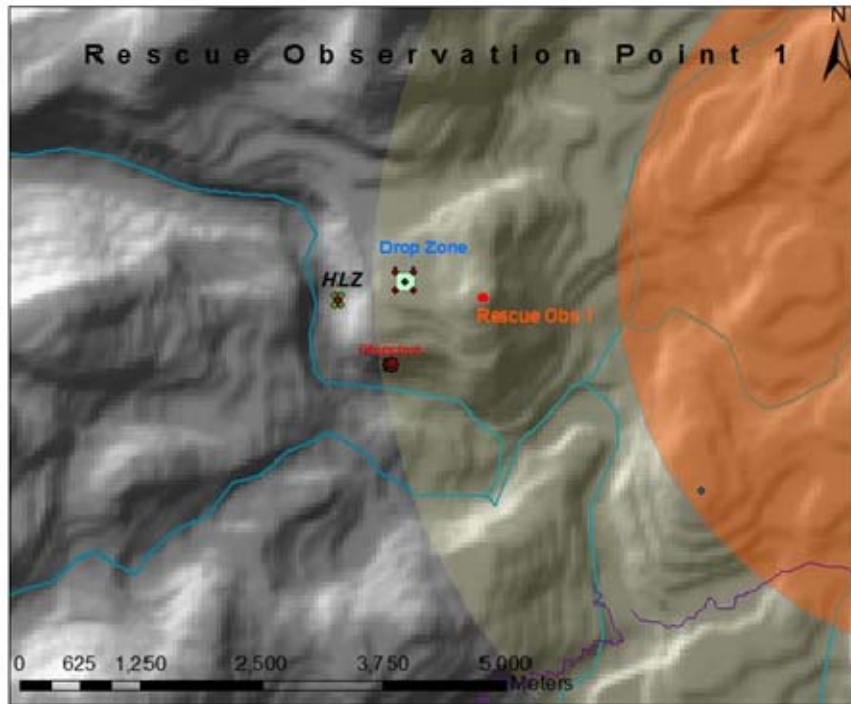
Figure 80.   SOF Unit observation point 1 obtained by means of Military Analyst> Find Highest Point tool
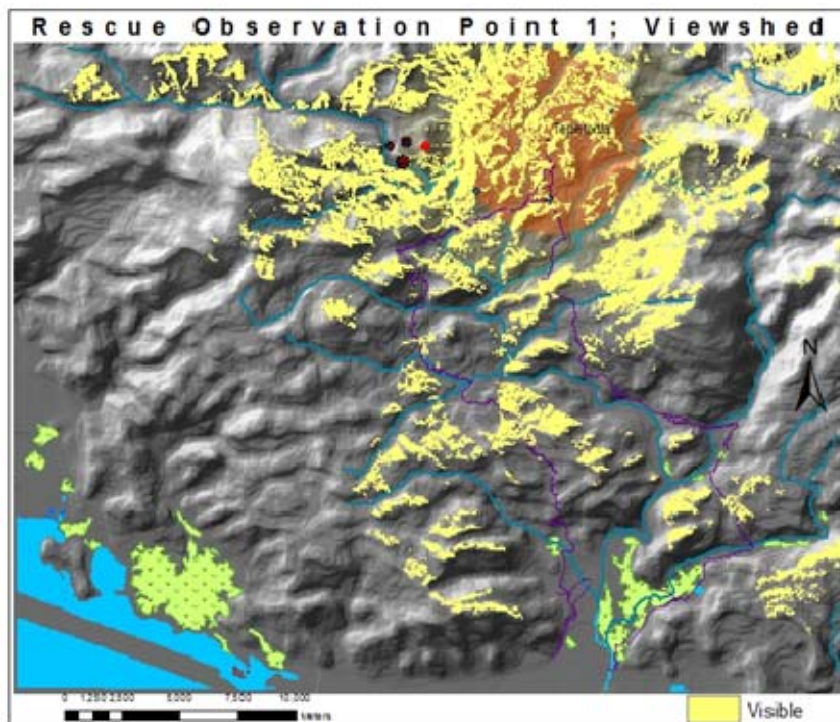
Figure 81.   SOF Unit Observation Point 1 viewshed

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By analyzing the observation point 1 viewshed (obs1_view), the SOF commander determines that it has good visibility. However, for VHF communication purposes the point's viewshed does not cover the HLZ; in addition, the rescue force would not have VHF communication with the command and control post aboard the ship. Consequently, the GEOINT analyst is asked to find potential sites, wherein viewshed would cover both the rescue observation point 1and the HLZ, as well as to find an observation point that would serve as a communications' bridge among the rescue forces and the ship. Hence, by means of viewshed analysis, the analyst provides the SOF commander with two more rescue force's observation points.[165]

Once having the locations of the three rescue-force's observation points, he asks the GEOINT analyst to present a map with the viewsheds of the three rescue observation points. This map may allow the commander to analyze it visually and to determine whether the rescue observation points have good visibility of the area of interest, as well as to ensure that none of them is isolated from communication, Figure 82**.**

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[165] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 13** on p. **220** for further details on the geospatial analysis operations developed at this stage.
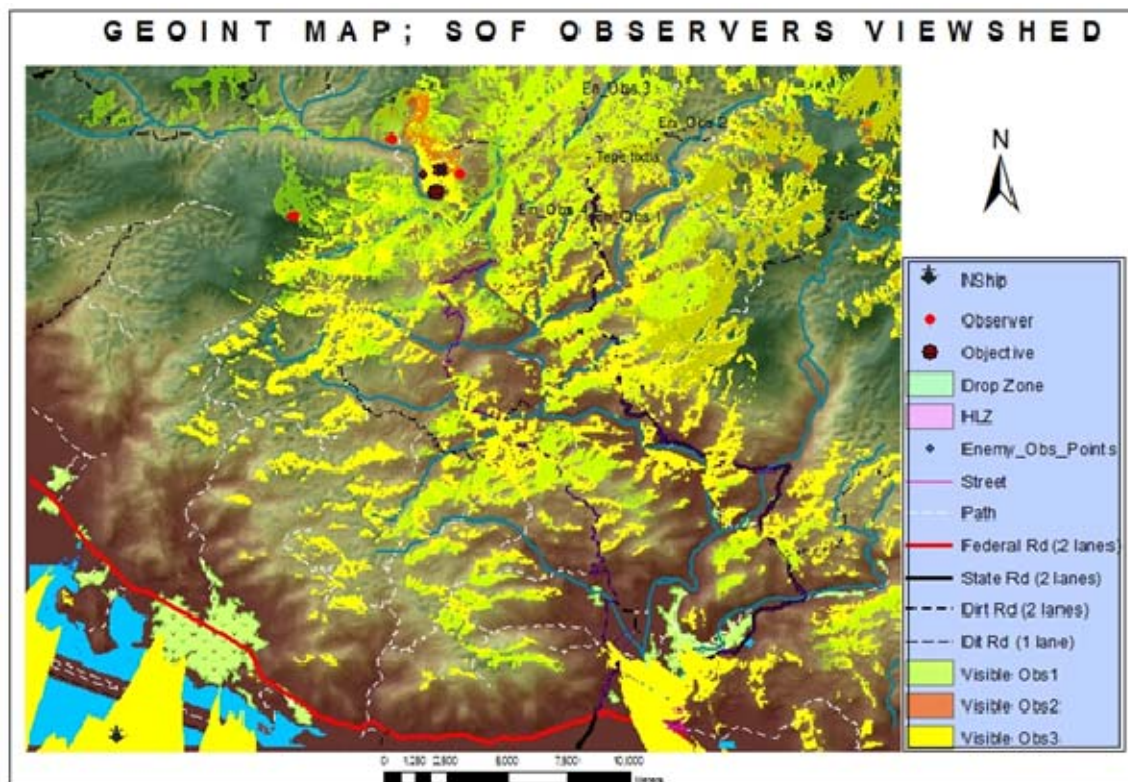
Figure 82.   SOF Observers Viewshed Map

As a result of the previous visual analysis, the SOF commander asks the GEOINT analyst to produce a map with the line of sight (LOS) from the rescue observation points' number 1 and 3 to the four enemy observation points. Hence, the analyst uses ArcGIS Military Analyst> Linear Line of Sight tool, which allows the GEOINT analyst to select the observer point and target. The result being a line feature where the color green (True) means that the observer is able to see that portion of the line, and the color red (False) means the portion that is not visible , Figure 83 and Figure 84.

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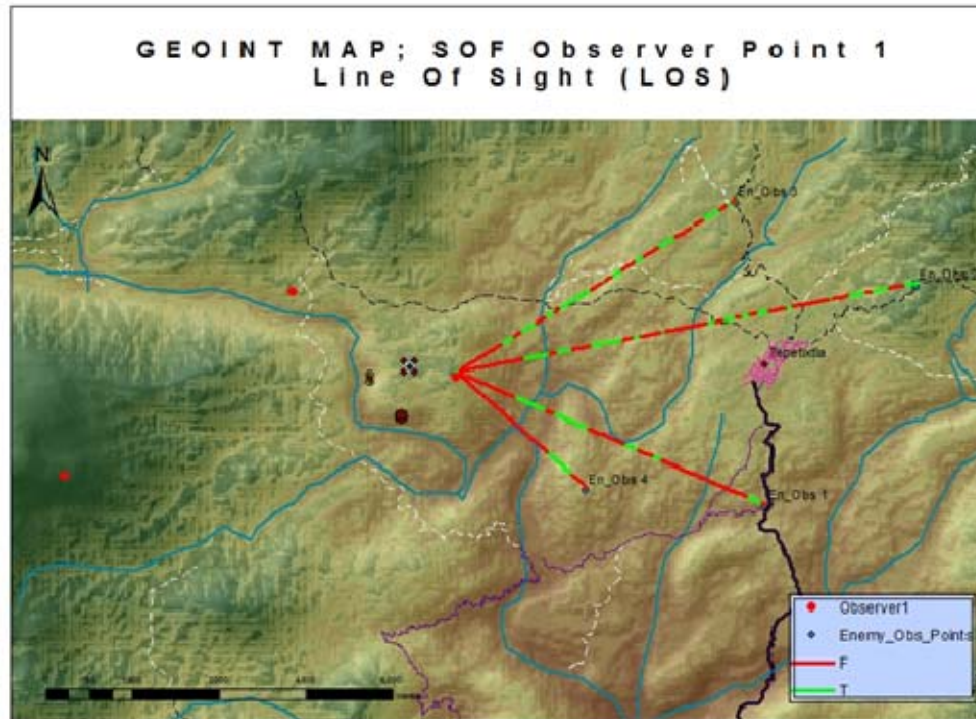
Figure 83. Line of Sight for the SOF observer point 1
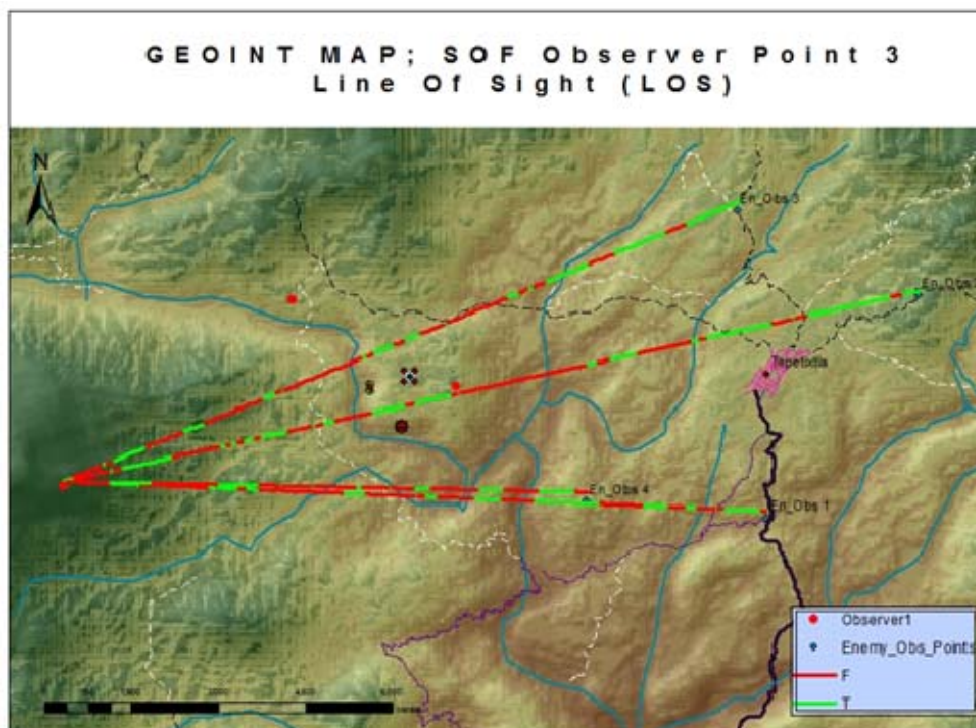
Figure 84. Line of Sight for the SOF observer point 3

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The next requirements from the SOF commander are two *less cost paths* for the rescue force, one from the DZ to the Objective and the other one from the Objective to the HLZ. Less cost path differs from the shortest path in the fact that the former takes into account not only distance but also many different factors (as many as the analyst considers) that affect the movement from one point to another, such as slope, vegetation, soil, and so on. The resulting paths are illustrated in Figure 85.[166]
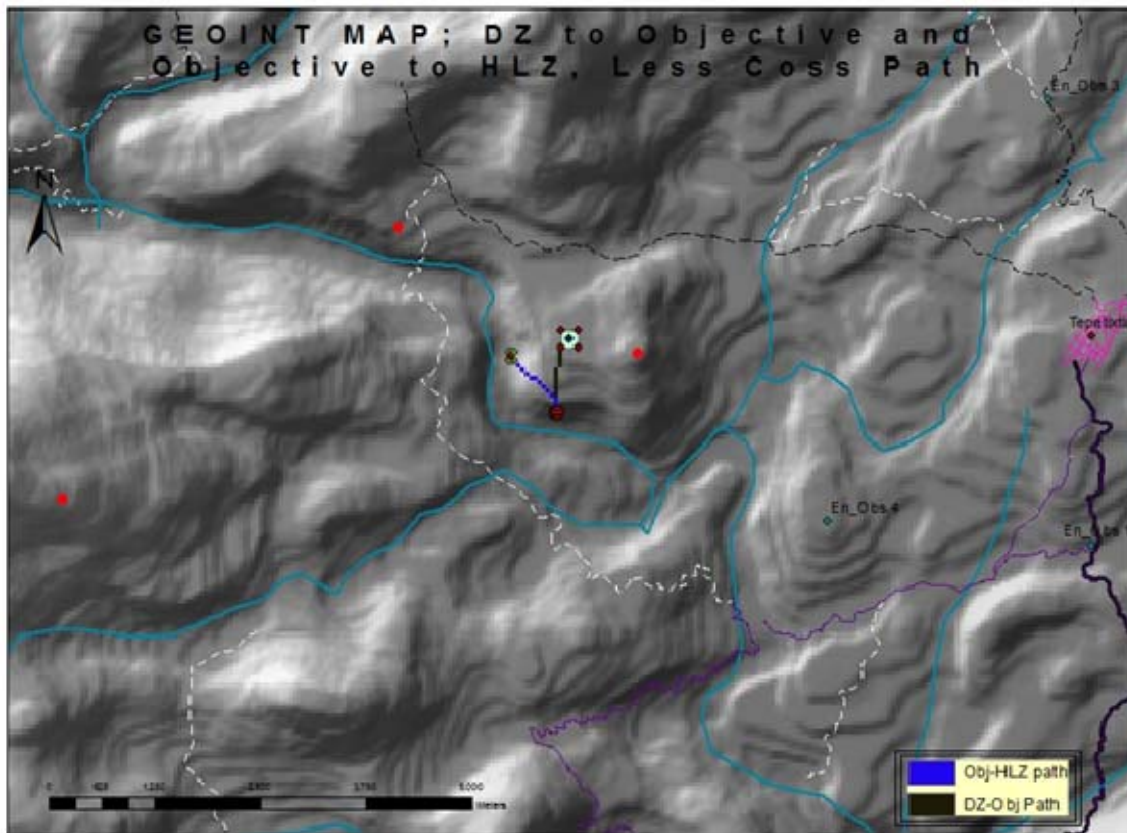
Figure 85.   Less Cost Paths for the SOF Rescue force

At this point, the SOF commander counts on the GEOINT required consolidating his planning. The GEOINT consists of the Area of Operations

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[166] Those with some knowledge of geospatial analysis can refer to **APPENDIX A section 14** on p. **222** for further details on the geospatial analysis operations developed at this stage.

topographic and Risk Maps, Enemy positions located spatially, as well as all of the locations for the tactical positions required for the execution, Figure 86.

Figure 86.   GEOINT Map: Tactical Positions

Prepare GEOINT for dissemination: as in the past GEOINT cycle, the GEOINT could be prepared in many different ways, depending on the consumer's preferences; in this case, the final product could be delivered on paper maps and graphics, in PowerPoint presentations, or directly through ArcGIS (2D) and ArcScene (3D) digital maps. In the specific case of the 3D maps, they could be presented in a video-clip, as well.

ArcGIS offers the capability of generating geographical grids to the maps so that they can be used by the operational forces in the planning and execution of their operations. These grids can be created in UTM, geographical coordinates with as many divisions as required. In addition, the analysts can create their own

coordinates system grid. In this case, because the operation involves Sea, Air, and Ground Forces, two kinds of grids are required: one in UTM, to be used by the Ground Forces, Figure 87, and another in geographical coordinates, to be used by the crew of the Navy ship, Figure 88. In this case, the maps had to be reduced in size to fit into the pages of this work; consequently, some of the features cannot be seen in detail. However, the GEOINT map products can be printed, with the adequate techniques and printers, in the size and quality required by the consumer without losing their precision.

Figure 87.   GEOINT Operational Map in UTM
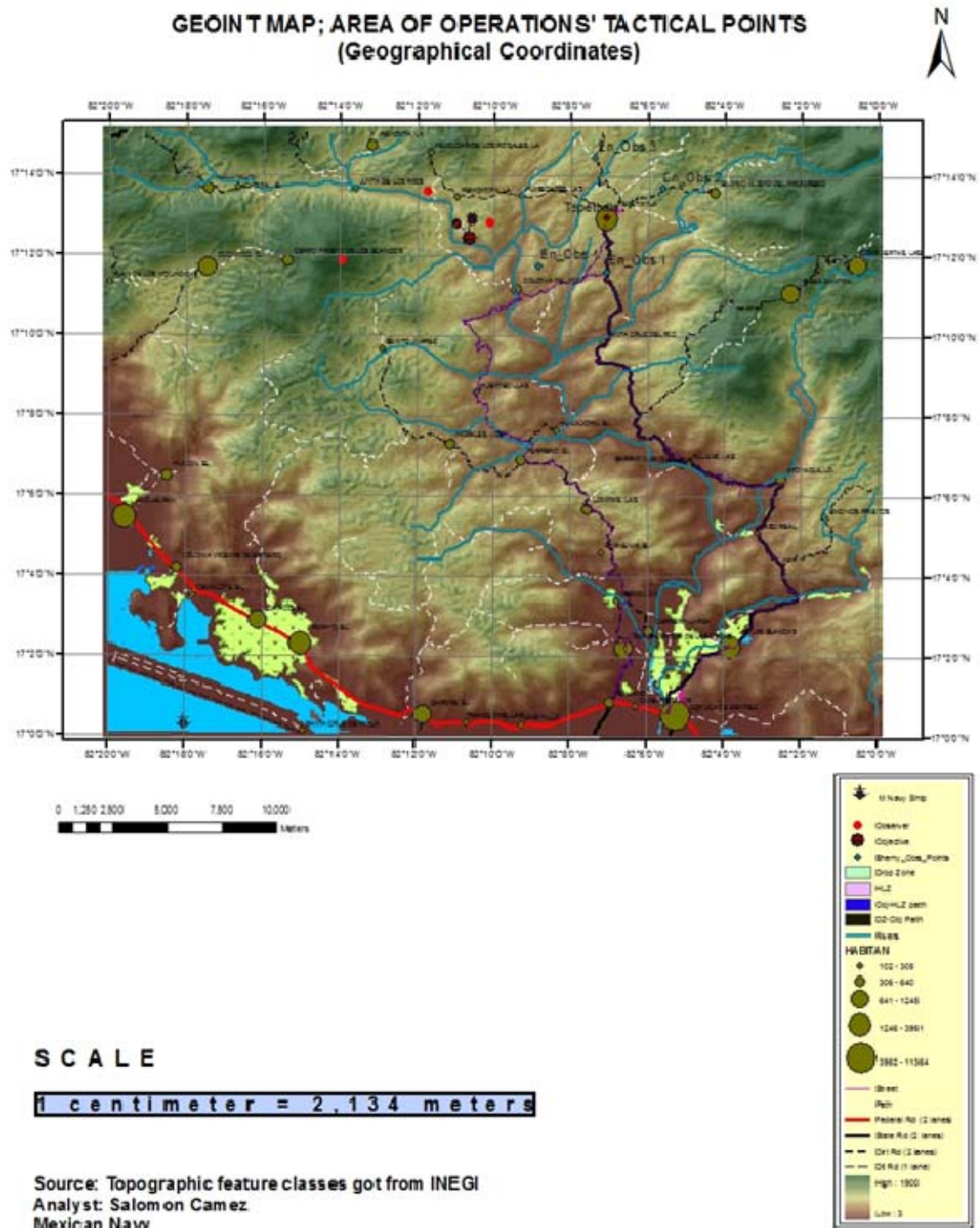
Figure 88.   GEOINT Operational Map in Geographical Coordinates

5.   Dissemination

Done

6.   Evaluation and Feedback

Done

The development of this simple scenario illustrates the enormous support to the decision making process in military operations that can be provided by GEOINT and its component Geospatial Analysis. In addition, it provided an example of the important potential of ArcGIS analytical software that has the capability of combining all the possible factors involved in a given operation.

One can appreciate this kind of analysis as helpful from the strategic level down to the tactical level of military and intelligence operations because in this kind of operations, the factor space is always going to be present. However, it is worth noting, that the software will not deliver precise results by itself, nor will it replace the knowledge and experience of the decision-makers. Hence, potential GEOINT analysts will need more than ArcGIS to complete a GEOINT analysis. Knowledge in the intelligence and military fields are required, as well as adequate training in the use of ArcGIS. Similarly, the military decision makers may be required to know about the capabilities of the analytical software as well as the GEOINT analysts under their command. Hence, "Mexican Navy effective GEOINT" involves counting on an adequate GIS network structure integrated by analysts, software, and hardware as well as the capability of training analysts in GEOINT applications in the intelligence and military fields with relative independence from commercial trainings.

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V. THE WAY AHEAD; MEXICAN NAVY SEIZING ON GEOSPATIAL INTELLIGENCE

> Generating, strengthening, and coordinating the intelligence systems in the Federal Government. The technological tools that will be developed in the information field will be the basis of the progress of the different institutions in their labor of generating intelligence.
>
> — **Mexican President Felipe Calderón.** Strategy 7.2 of Mexico's *National Development Plan (2007 – 2012).*

As we learned in earlier chapters, GEOINT has nearly unlimited applications for use in the military and intelligence fields. By applying GEOINT effectively, the Mexican Navy may become more proactive from the strategic down to the tactical levels of military personnel, and GEOINT may significantly increase their effectiveness with the resultant savings of time and resources.

However, the Mexican Navy will not utilize GEOINT in Mexico purely through training. Therefore, an adequate infrastructure that is integrated by professional analysts, software, GIS networks, and other hardware are required in order to secure an effective application of GEOINT.

Consequently, this chapter analyzes the GEOINT status in the Mexican Navy by giving an overview of the GEOINT status in Mexico and the current situation of GEOINT in the Mexican Navy structure. Such an analysis may identify the degree to which the Mexican Navy is taking advantage of the GEOINT applications and determine what can be improved in this institution to make the most of GEOINT. Once having determined what needs to be improved, the author will develop a preliminary approach for a subsequent project for the enhancement of the GEOINT capabilities in the Mexican Navy.

A.   OVERVIEW OF GEOSPATIAL INTELLIGENCE IN MEXICO

Mexico has joined with the large number of countries that are well aware of the significance of GEOINT in security and development and is focused toward efforts and resources in the development of the field. Consequently, at the Mexican Governmental Institutions' level, the cornerstone of GEOINT had been laid in late 2003 when the Mexican President, at that time, Vicente Fox inaugurated the *Estación de Recepción Satelital México*, ERMEXS (Satellite-Reception Station Mexico). In charge of the installation, custody, and operation of ERMEXS were the Mexican Navy and the *Secretaría de Agricultura, Ganadería, Desarrollo Rural, Pesca y Alimentación* SAGARPA (Secretariat of Agriculture, Livestock, Rural Development, Fishing, and Food). Nowadays, these institutions continue to be in charge of ERMEXS' operation with the addition of the *Instituto Nacional de Estadística y Geografía,* INEGI (National Institute of Statistics and Geography, Mexico) into the formula. [167]

ERMEXS is in charge of the gathering and processing of the imagery from three satellites of the "Spot constellation" that were launched by the French *Centre National d'Etudes Spatiales*, CNES (National Center of Spatial Studies) with the support of Sweden and Belgium and operated by the company Spot Image. These satellites cover an extension of territory that includes the south of the U.S., Mexico, Cuba, and Central America. These satellites have the capability of capturing medium and high-resolution surface images of the earth. ERMEXS provides Mexican institutions with the necessary information products to support control, prevision, and processes of resources and human activities. In addition, it represents an efficient and economical means of support for the decision making process.[168]

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[167] SEMAR, "Ciencia y Tecnología. Investigación," Secretaria de Marina, Armada de México, http://www.semar.gob.mx/investigación/index.html, (accessed date 8/1/ 2008).

[168] Ibid.

Among the governmental institutions, the military ones are now using the imagery provided by ERMEXS to fulfill some of their missions. Therefore, the Mexican Navy uses the imagery for oceanographic investigation, ports' development, nautical cartography elaboration, intelligence, and maritime traffic. On the other hand, the Mexican Defense Secretariat (Army and Air Force) uses the imagery for topographic cartography development to support intelligence labor and tactical exercises.[169]

One of the characteristics of ERMEXS' system to be highlighted is the fact that it has a multi-user's license at the government level. This allows the use of the imagery as required by the institutions at the three levels of government (federal, state, and municipal) as well as universities and public schools at the superior level of education for the development of scientific investigation.[170]

Nowadays, the Mexican Government Institutions rely on GIS and the required software for the managing, processing, and analysis required in the GEOINT process, also using ArcGIS. [171] These resources provide the support platform for the integration and sharing of GEOINT among them. Additionally it multiplies the GEOINT capabilities of the involved institutions to support their decision making process in a given situation that may require information or GEOINT products from different fields.

Even though GEOINT is a relatively recent discipline within Mexican government institutions, they have enhanced this capability in an effective way, because they have developed the mechanisms and structures to exploit imagery and IMINT. However, there is still something very important to be carried out, specifically by Mexican Military institutions, and that is the effective exploitation of Geospatial Analysis and its integration as the third component of GEOINT.

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[169] SEMAR, "Ciencia y Tecnología. Investigación," Secretaria de Marina, Armada de México, http://www.semar.gob.mx/investigación/index.html (accessed date 8/1/2008).

[170] Ibid.

[171] Information obtained from a personal communication with the Chief of the GEOINT Group of the Mexican Navy General Staff.

Disregarding geospatial analysis, or not exploiting it effectively, exponentially reduces the GEOINT capabilities of military institutions because one of the greatest attributes is that it allows GEOINT analysts to develop complex analyses using large amounts of spatial data that would not be possible by other means. In addition, it is worth recalling that an image is a single shot in space and time.

A non-military entity that appears to have recognized the significance of integrating geospatial analysis in the GEOINT context is the *Sistema Nacional de Seguridad Pública*, SNSP (National System of Public Security) with the implementation of the C4 system. The C4 system is integrated by C4 centers, with the personnel and technological infrastructure required to provide public security corporations with the tools needed to attend emergencies, and coordinate among corporations with strategic information, among many others. There is at least one in each Mexican State and all of them are intercommunicated by an internal network. Every C4 center relies on GIS and the access to geographical data through their internal network. This capability allows the analysts not only to provide the operators, who respond to an emergency, the precise location and spatial information of the area of the incident, but also to develop pattern analysis about the incidents to determine the focus on given areas, crimes or risks.[172] This is illustrated in Figure 89 where the C4 center of Baja California, Mexico, generated a GIS-analysis-report that relates crime incidence with emergency calls.

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[172] SSP BC, "Centros De Control, Comando, Comunicación y Cómputo (C4 Baja California),"
http://www.ciapem.org.mx/work/sites/CIAPEM/resources/PDFContent/160/Jose%20de%20Jesus%20Valenzuela%20Fraijo.pdf (accessed date 9/7/2008).
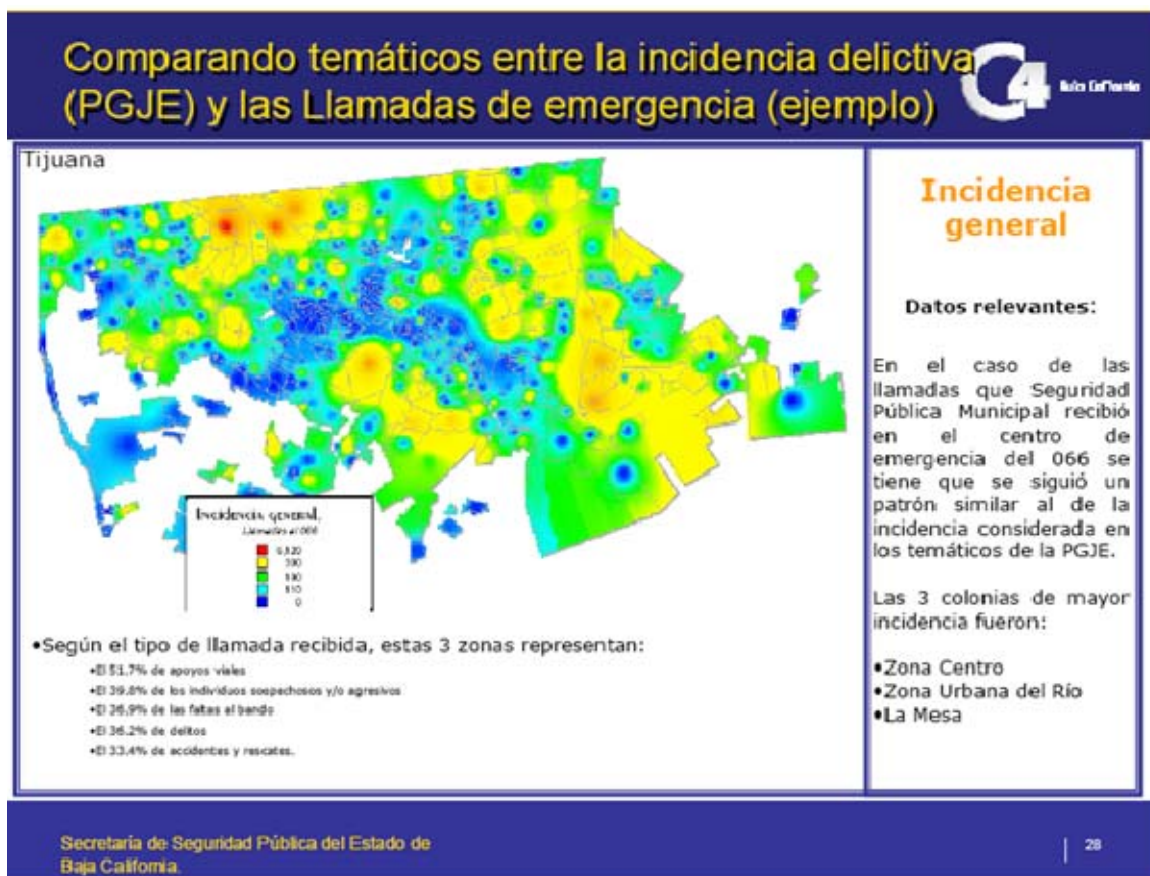
Figure 89. C4 center of Baja California generated a GIS analysis report that relates crime incidence with emergency calls. Red are the areas that obtained a higher value[173]

In addition, C4 centers coordinate and share information with the military at the federal, state, and municipal levels. However, at the state and municipal levels, the Mexican Navy does not rely on GIS infrastructure, or at least with GIS software that would favor the sharing of information.

In order for geospatial analysis to be exploited effectively by Mexican Military institutions, GEOINT analysts need to be adequately trained;

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[173] Retrieved from http://www.ciapem.org.mx/work/sites/CIAPEM/resources/PDFContent/160/Jose%20de%20Jesus%20Valenzuela%20Fraijo.pdf , (accessed date 9/7/2008).

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unfortunately, none of the trainings in geospatial analysis in Mexico is oriented for military or intelligence analysts. That is because the entities that offer such trainings are commercial entities or educational institutions.

While the Mexican military still needs to seize on geospatial analysis to enhance its GEOINT capabilities, when considering geospatial analysis as an independent activity, it will be argued that Mexican educational and other civilian institutions, as well as commercial brands are seizing on that activity effectively. This is because technological advances broadened from being controlled solely by military institutions all around the globe. In addition, market competition has pushed commercial entities to research and develop state of the art technology that is sold to anyone who can afford the costs.

Furthermore, globalization has helped reduce the rigors of regulation and other constraints that limited the spread of new technology in the past. Hence, nowadays, many civilian and commercial entities are effectively exploiting the benefits of geospatial analysis. Some of them have even established their own departments of research, training, and development on GIS while the Mexican Military Institutions still do not rely on these kinds of departments for the exploitation of GIS in the military and intelligence fields.

For example, the *Centro Nacional de Prevención de Desastres*, CENAPRED (Government Agency for Disasters Prevention), relies on a research area named *Sistema de Información Geográfica del Atlas Nacional de Riesgos* (GIS national risk atlas) that is under the "direction of research" of that institution. The mission of this research is to collaborate in the generation of geospatial information generated in the CENAPRED about the dangers, vulnerability, and risks in Mexico, which is made by means of an integral information system about the risk of disasters, ultimately resulting in support of activities of the civil defence authorities.[174]

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[174] "CENAPRED," http://www.cenapred.unam.mx/es/Investigación/Atlas/ (accessed date 10/8/2008).

In addition, many Mexican superior education institutions have training, research, and/or development areas focused on GIS, such as the case of *Universidad de las Américas de Puebla* (Americas' University of Puebla) with its geo-informatics technology laboratory[175] and the *Instituto Politécnico Nacional*, IPN (National Polytechnic Institute) with its intelligent laboratory of geospatial processing under the computation research center.[176] Within the Mexican universities the one that stands out in GIS training, research, and development is the *Universidad Autónoma de Mexico*, UNAM (Mexico's National Autonomous University). The Geography Institute in the UNAM relies on a Geospatial Analysis' Laboratory that not only embraces research and development in GIS but also remote sensing. Some fields of research of this laboratory include marine and alternative remote sensing, natural resources monitoring, digital images processing, spatial analysis, digital cartography and visualization, spatial modeling, spatial decision-making support, and spatial data infrastructure.[177]

Hence, taking into consideration that GEOINT in Mexico is relatively new, one could argue that it is performing well in that regard; however, there is still work to be done by the military institutions in order to enhance their GEOINT capabilities. The fact that space is embedded in every single military operation demands the effective integration of geospatial analysis in the GEOINT formula, in order to provide commanders with effective GEOINT that supports their decisions, resulting in a savings of time and resources. In the civilian context, Mexico development of the geospatial analysis activity is outstanding, and the entities that are involved could possibly provide excellent support to the military

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[175] "GISUDLA - Laboratorio de Tecnologías de Geoinformación," http://ict.udlap.mx/activities/GIS/html/propuestas_tesis.html (accessed date 10/8/2008).

[176] "Laboratorio de Procesamiento Inteligente de Información Geo-Espacial | CIC: Posgrado," http://posgrado.cic.ipn.mx/?q=mcc.piig.grupo (accessed date 10/8/2008).

[177] "Laboratorio de Sistemas de Información Geográfica y Percepción Remota," http://www.igeograf.unam.mx/iggweb/l.html (accessed date 10/8/2008).

institutions when they decide to enhance their GEOINT capabilities. Nonetheless, the civilian/commercial approach of the models may need adaptations for the military and intelligence fields.

B.   MEXICAN NAVY AND GEOSPATIAL INTELLIGENCE CURRENT STATUS

Currently, Mexican military institutions face enormous challenges because they are dealing with global and regional threats that endanger Mexico's National Security. In the global arena, Mexico faces threats to national security as the case of terrorism while in the internal and regional arena it faces threats such as drug-trafficking and arms smuggling to name just some of the most important for the country.

Nowadays, organized crime and drug-trafficking are considered the largest threat to Mexican national security due to the increasing levels of drug-related-murders and guerrilla-like tactics used by these criminal organizations. As such, Mexican military institutions have been playing a significant role in executing joint operations with other federal institutions against these threats.

In addition to this complex environment, it is worth mentioning that, in the specific case of the Mexican Navy, it has an almost unique character, because it develops manifold and diverse tasks in the execution of its administrative and operational responsibilities. These diverse tasks are because the Mexican Navy is the only Mexican institution that has the capability of preserving the rule of law and for protecting the state in Mexican seas, acting as a Navy and at the same time as a Coast Guard. Moreover, it has jurisdiction over the Isles and inland on the continental-shoreline-strip. Hence, in order to cover its jurisdiction, the Mexican Navy executes diverse tasks that involve sea, land, and air operations.

Mexican Navy decision makers are well aware of the complex situation with which they are dealing ; consequently, they have devoted a significant part of their resources and effort to research and development in the military field, as

in the case of the design and construction of Navy vessels, optronic-fire-control-directors, radars, and night vision devices, to name just a few.

In addition, the Mexican Navy is knowledgeable of the changing global security environment created by non-state-actors who use new technologies and tactics to harm the rule of law and the sovereignty of the States. Consequently, the Mexican Navy has seized on new military technologies as well as improving its doctrines, education programs, and organizational structures to rely on commanders and other personnel with the ability for effectively facing new threats.

In addition, as seen earlier in this chapter, the Mexican Navy has been playing a significant role in the installation, custody, and operation of ERMEXS and it was the cornerstone of a continuous enhancement of the Mexican Navy's GEOINT capabilities. In 2004 the Naval institution created the *Subseccion de Información Satelital* SIS (Subsection of Satellite Information) as a part of a Section of Intelligence in the structure of the Navy General Staff. This new task in the intelligence section of the General Staff demanded trained people and a Geospatial Information System (GIS) to execute it. Therefore, people in the GEOINT group of the SIS were trained in remote sensing, visual analysis, and the geospatial analytical software that he SIS now relies on as a part of its GIS, which are ERDAS and ArcGIS packages.[178]

This new support in the intelligence structure of the Mexican Navy has resulted in a significant improvement of the effectiveness of its operational units. For example; in July 2008, Mexican deputies emphasized the outstanding work of the Mexican Navy Intelligence System and congratulated the Secretary of the Navy. In that event, the policy makers lauded the recent achievement of the Mexican Navy, which was the interception and seizure of a ten-ton Colombian submarine that was trafficking with about six tons of cocaine in Mexican waters.

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[178] Information got from a personal communication with the Chief of the GEOINT Group of the Mexican Navy General Staff

This successful operation was completed thanks to the effective execution of interdiction operations at sea by the Navy vessels with the support of Navy intelligence.[179]

Hence, GEOINT has proved to be a significant tool in the performance of Mexican Navy intelligence. However, because this discipline is starting to evolve in Mexico, there is still work to do in order to enhance GIS and GEOINT in the Mexican Navy. This is because the GEOINT capabilities are still concentrated in the General Staff. This means that the Operational Forces, on the field (Navy Forces, Regions, and Zones), do not rely on the same analytical software yet (as the case of the SIS) nor on the required GEOINT analysts to develop their own GEOINT process independently from the General Staff, as is demanded by the ever-changing environment, Figure 90.

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[179] *Felicitan Diputados a SEMAR Por Captura De Narco Submarino*, 8/5/2008.
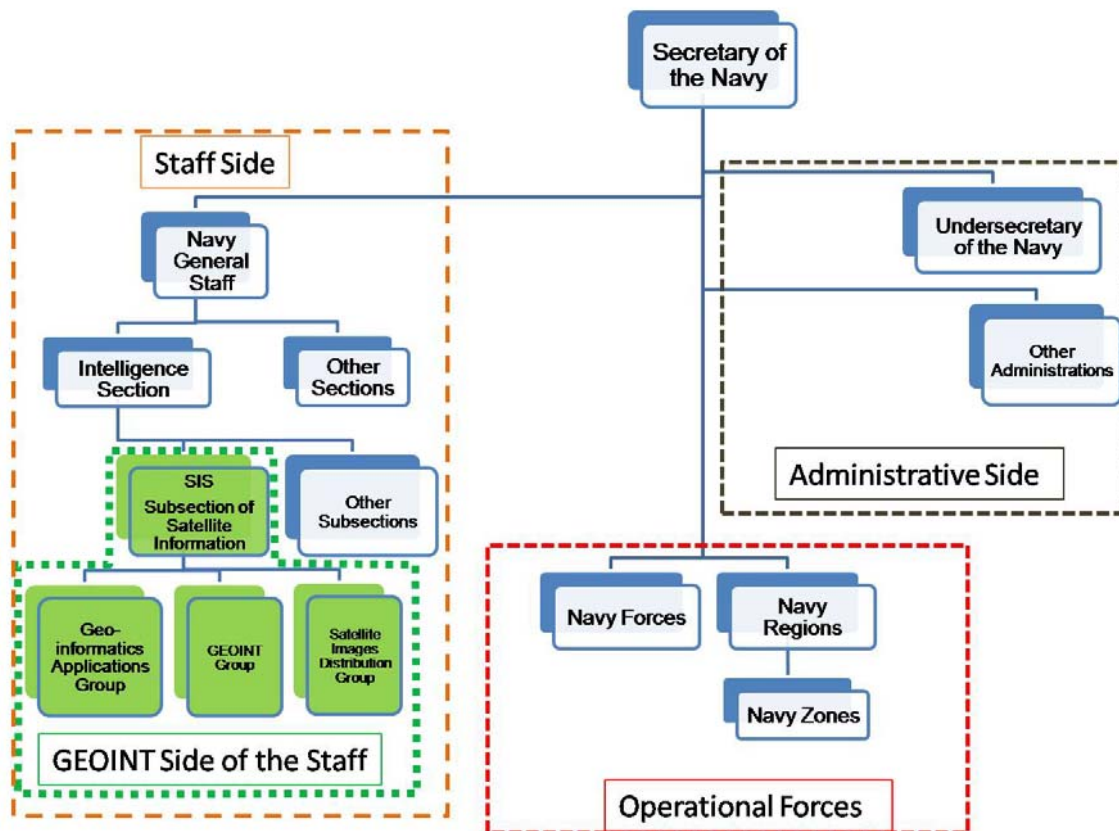
Figure 90.   Basic organizational chart of the Mexican Navy, showing the position of the groups in charge of the GEOINT (green boxes)[180]

Leaving operational commanders with only the GEOINT they receive from the SIS would result in operational forces wasting valuable time and resources in planning and improvising with such a "static" GEOINT. Alternatively, commanders could be requesting GEOINT back and forth to the SIS in any situational change. In addition, the only GIS tool for the operational commanders would be the visualization of already processed images. This limitation constrains the operational decision makers to just executing, with the support of computer systems, to visual analysis. Needless to say, the operational commanders are

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[180] Based on
http://www.semar.gob.mx/planilla_organica/imagenes/edomay/jem/subjef_operativa.gif ,
(accessed date 8/14/2008).

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the ones who are *in situ* as well as knowledgeable of what is happening and what resources (human and material) they have available for execution of the operation.

Furthermore, GEOINT-capabilities-centralization would overload the SIS because their members would have to develop every given GEOINT process for the operational forces "on the field." In addition, the training for the GEOINT analysts available in Mexico do not involve military or intelligence approaches, this situation gives GEOINT analysts an extra task of looking for ways to adapt the knowledge to the military field. Figure 91 illustrates the primary diverse tasks that the SIS, as the only entity with GIS capabilities, may have on the staff. It is worth mentioning that this may not be the only tasks the SIS executes in its everyday performance.
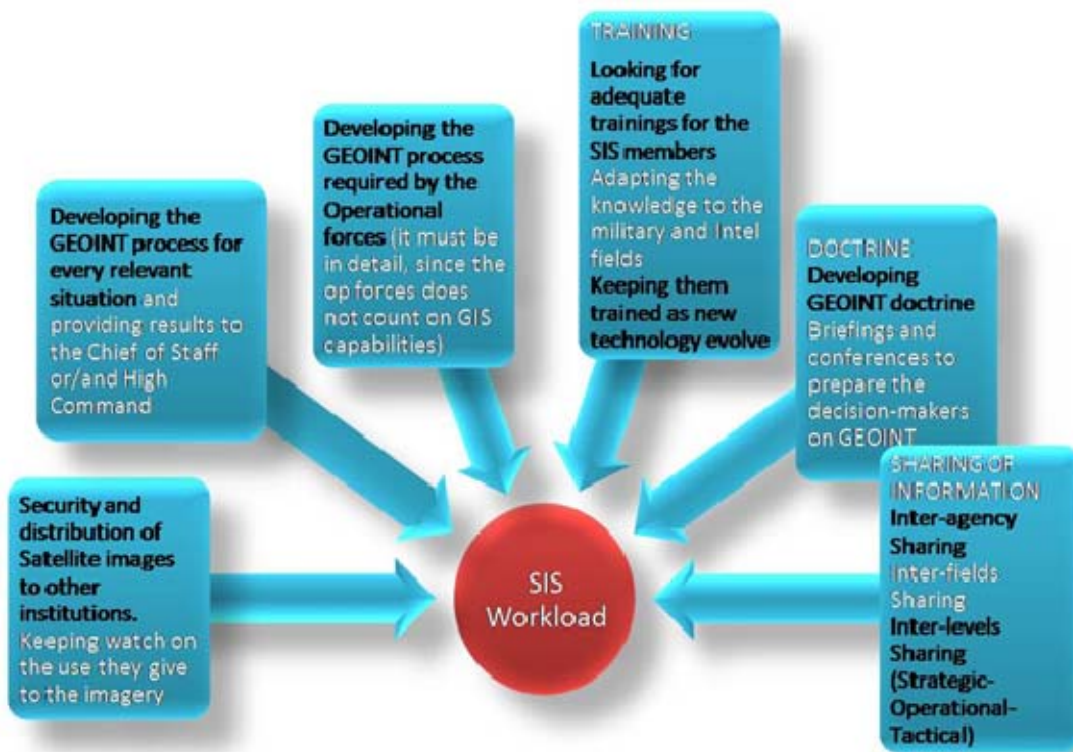
Figure 91.   SIS Workload given by its main tasks

At the operational levels, the GEOINT capability would provide them with significant support for the decision making process. An example of this is the GEOINT support to a SOF rescue operation, developed through the GEOINT-process-model and presented in chapter IV, where hypothetically the Pacific Navy Force counted on GIS software and its GEOINT analyst for developing the analysis, and giving the command enough independence and flexibility to produce effective GEOINT. The GEOINT process could hardly be developed effectively without being in direct collaboration (*in situ*) with the operational commander and his staff, as well as the subordinated commanders involved in the operation.

Another inconvenience of the SIS overload may be that it would not be able to perform effectively its most important mission-- that is to provide the General Chief of Staff (and the High Command when required) with the appropriate GEOINT of every relevant situation.

In addition, the demand on GEOINT and imagery products may follow a natural trend going upwards because as the decision makers and GIS operators inside and outside the Mexican Navy become aware of the support provided by these products, demand may increase. For example, ERMEXS delivered 5,892 satellite images in 2004, while in 2005 the demand increased to 13,870 images[181]; hence, the increment was more than two times each year. Therefore, the natural consequence of the imagery-demand's increment is the increment on the SIS workload, as time goes by.

In February 2008 the Mexican Navy created the *Unidad de Inteligencia Naval*, UIN (Navy intelligence Unit), which will be formalized until it is officially recognized by the congress. UIN would play the role of governing-body of Navy intelligence at the strategic, operational, and tactical levels, moreover as a link with other intelligence entities in the federal public administration and other levels

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[181] "Modelo de Identificación de Áreas Costeras con Probabilidades de Ser Inundadas a Causa de un Maremoto (MIACIM)," http://innova.fox.presidencia.gob.mx/archivos/0/1/5/1/files/archivos/sip-5081.pdf (accessed date 9/27/2008).

of government. In addition, the UIN would be equipped with technology that allows automating the intelligence cycle to make the information process more effective and secure.[182]

In spite of the fact that the organizational structure of the UIN has not yet been established, it is important to consider GEOINT as a component in it. In this way the UIN certainly may relieve the overload the SIS now has, but expansion of GEOINT capabilities to the operational levels may still be considered. In addition, it is worthwhile for the UIN to consider the institution of professional training on GEOINT for intelligence officers and the creation of an entity for the training and development of geospatial analysis and GIS analytical software. These approaches will be explained later in this work. The proposed measures may be considered by the UIN; otherwise the GEOINT overload that the SIS now has would change hands but would continue being centralized.

C.   PRELIMINARY APPROACH FOR THE ENHANCEMENT OF THE GEOINT CAPABILITIES IN THE MEXICAN NAVY; PROPOSED ACTION LINES

The importance of this preliminary approach is based on the fact that currently GEOINT and GIS are becoming significantly more important in the military and intelligence fields. Consequently, it is necessary that the Mexican Navy take, rather rapidly, a firm step into the competitiveness of the GIS and other information systems' arena. By becoming involved now in the GIS and GEOINT fields, the Mexican Navy would rely on analysts as professionals. Analysts would have the knowledge required to take what the Mexican Navy would need from the enormous vault of information systems' innovations that are offered by the commercial labels. Conversely, by not seizing this opportunity, the Mexican Navy would waste resources when it comes to the acquisition of new information technology that may not be the best for the Mexican Navy or military purposes. It is worth recalling a previous source from Chapter II:

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[182] Secretaría de Marina, *Segundo Informe De Labores (2007-2008)*, ed. SEMAR (Mexico: 2008), 52.

In recent years, targets have gone from static to mobile; time frames, from months to minutes; new forms of denial and deception have been employed; and targets have moved both underground and into civilian and more uncharacterized contexts.[183]

Nowadays, Mexican Navy Commanders at every level have an enormous responsibility on their hands, which includes "responding quickly and effectively to the constantly changing challenges posed by new and complex threats to the Mexican National Security." Consequently, the knowledge and dominance over the information systems that support the decision making process is not an option; it is a necessity for military institutions. Failing to seizing on the innovations at this time would result in a waste of resources and in all likelihood result in ineffective responses to the everyday, more complex security environment.

Now the Mexican Navy counts on remote sensing and its derived imagery capability; as such, this is a great step into the digital age. Photo-interpretation as explained in chapter II, provides Navy intelligence with excellent support in the decision making process. However, using the GIS software just for IMINT is to leave out a very important element of GEOINT, which is geospatial analysis.

Asserting that the approach presented here considers every factor involved for its implementation would be a negligent statement. However, this preliminary approach could be the foundation of a larger, detailed project. Exhaustive planning, teamwork, and research may be developed in the Mexican Navy's environment for shaping this approach until a sound project , which is in concordance with the resources available, as well as the Commanders' and experts' recommendations, can be reached. This preliminary approach looks at developing action lines that may aim toward the aspects established in this work. Hence, the following list presents statements about the aspects found and previously highlighted in this thesis that should be considered in developing the plan of action:

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[183] National Research Council (U.S.) and others, *Priorities for GEOINT Research at the National Geospatial-Intelligence Agency*, 11.

- GEOINT and its embedded GIS and software have almost unlimited application in the military and intelligence fields for the Mexican Navy.

- GEOINT may be understood as comprising its three components: Imagery, IMINT, and Geospatial Analysis that complement each other.

- Related to the last statement, Mexican military institutions has tended to exploit mainly Imagery and IMINT, ignoring the very significant GEOINT component that is geospatial analysis.

- Mexican Navy GEOINT capabilities are centralized in the staff, leaving the operational commands without GEOINT capabilities and overloading the SIS.

- The recently created UIN may consider GEOINT as a component in its structure. In addition it may consider other GEOINT and GIS structures that support it, to avoid repeating the SIS centralization and overload.

- Professionalization and training on GEOINT and GIS analytical software is highly significant when considering that GEOINT would support sensitive decisions from the strategic down to the tactical level.

- Related to the last statement, the GEOINT analyst requires a military oriented training on GEOINT and GIS analytical software.

This preliminary approach is based in the following action lines:

- Providing the Mexican Navy Intelligence School with GEOINT instructors.
- Providing the UIN and operational commands with GIS and GEOINT capabilities.
- Creating and implementing a Training, Research, and Development Lab in analytical software for the Mexican Navy.

The author of this thesis in building these action lines is considering training as the key for the Mexican Navy's success on GEOINT and GIS. This is because , as noted in chapter II, the diversity of situations that the GEOINT analysts must solve in looking for intelligence., There is no single way to develop the GEOINT analysis. On the contrary, due to the large number of tools and functions that the GIS relies on currently, the ways to develop the analysis are

almost limitless. The GEOINT analysts need to be highly trained in the use of GIS analytical software. This would allow them effective exploitation of the product, as well as the ability to test GEOINT results from different perspectives.

The first focus on training may be the formation of an instructors' cadre for the Intelligence School and for the training and research lab aforementioned. The next step may be the development of, military and intelligence oriented GEOINT and GIS training programs focused on the actual requirements of the Mexican Navy. As a result, the Mexican Navy would generate its analysts based on its own training programs to fulfill the requirements at the Staff, UIN, and Operational Forces levels.

GEOINT and GIS training in the Mexican Navy may function as a multiplier effect by the generation of new analysts, and at the same time they may favor the sharing of GEOINT, integration of information, and collaboration among different intelligence entities. This collaboration among the intelligence entities may be obtained through the doctrine acquired in the GEOINT and GIS trainings, which may provide analysts who speak the same GEOINT language. Consequently, they may manage the large GIS datasets in the same way.

Furthermore, the instructors' cadre (and the researchers as will be seen later) may be the means for the Mexican Navy to keep current on new methods and technology by actualizing the current and future analysts in these innovations. This point is highly important due to "the knowledge gap" that is described by Tomlinson as "…a phenomenon that results from the new capabilities of technology growing faster than an organization's ability to use them." He also establishes that before 1990 there was no knowledge gap in the GIS technology development because "…people were still more capable than their GIS systems." However, "By 2000, the rate of GIS development had risen above the normal growth trend of institutional management skills."[184] (Tomlinson 2007, 238) Figure 92 illustrates this trend.

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[184] Roger Tomlinson, *Thinking about GIS; Geographic Information System Planning for Managers*, Third ed. (Redlands, CA: ESRI Press, 2007), 169.
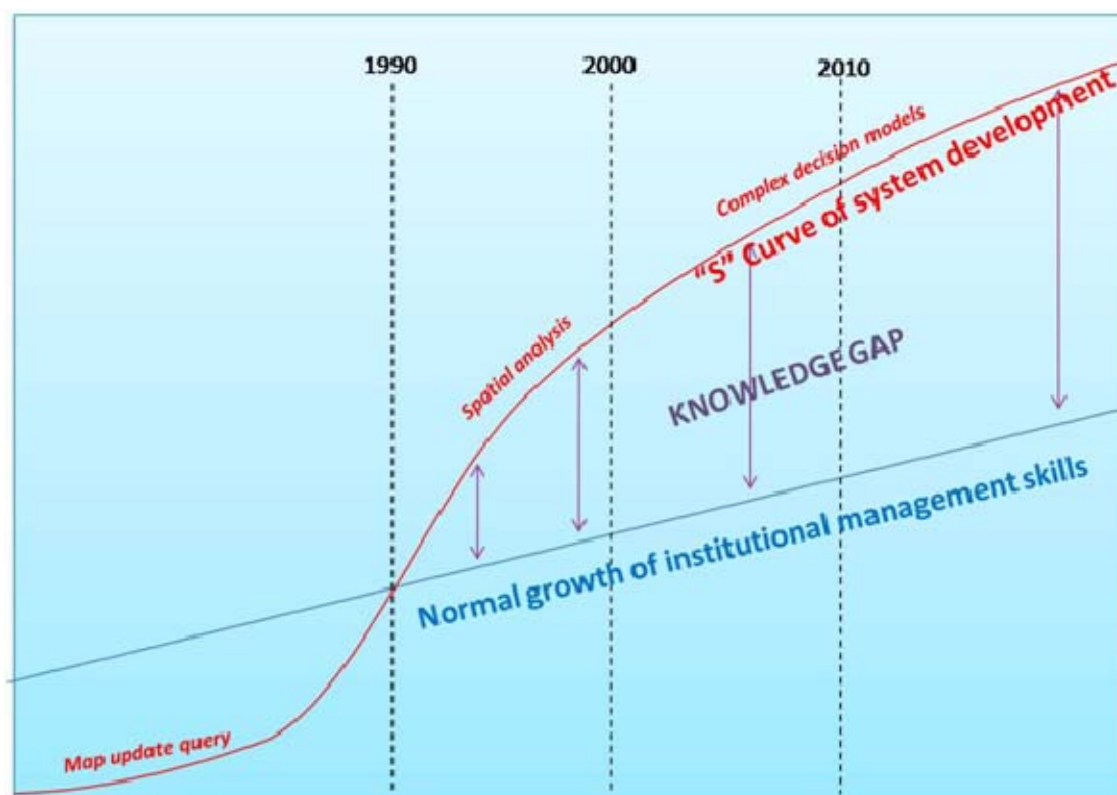
Figure 92.   GIS technology: Accelerating faster than the skills to use it[185]

1.   Action Line: Providing the Mexican Navy Intelligence School with GEOINT instructors

The Intelligence School offers training for future intelligence officers in the Mexican Navy. Relying on GEOINT instructors in this school would create an opportunity to specialize the intelligence officers who need preparation in the GEOINT field. This capability may provide the various levels and units in the Mexican Navy with intelligence officers who have the ability to execute the GEOINT process in an effective manner when required.

In preparing the Mexican Navy GEOINT instructors, the author recommends using the GEOINT training model of the U.S. School of Geospatial

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[185] Roger Tomlinson, *Thinking about GIS; Geographic Information System Planning for Managers*, Third ed. (Redlands, CA: ESRI Press, 2007), 169.

Intelligence (TSG) at the NGA College. That School's mission according to Colonel Stuart Harrison, Commandant of the school is

> …to train and educate geospatial intelligence in all forms for the DoD, the intelligence community, other federal agencies—which is a huge and growing mission for us—and our international partners. Our perspective of training GEOINT is according to the National System for Geospatial Intelligence [NSG].[186]

The TSG divides the GEOINT training according to the GEOINT components; on the one hand, it prepares imagery analysts (IAs), who embrace the imagery and IMINT components, and geospatial analysts (Gas), who embrace the geospatial analysis component, on the other.[187]

Hence, the Mexican Navy Intelligence School may cover its basic need for GEOINT instructors by preparing at least an IA instructor and a GA instructor. In preparing these instructors, the Mexican Navy may look for an agreement with the NGA to send two intelligence officers to take the IA and GA courses provided by the TSG. However, if that is not possible there are many universities in the U.S. and in Mexico that provide education in areas such as remote sensing or/and imagery interpretation, for preparing the IA instructors and geospatial analysis, for preparing the GA instructors. For the last option, further research and development may be done to create GEOINT programs to be applied for the instructors in training the Mexican Navy intelligence officers in GEOINT.

2. Action Line: Providing the UIN and Operational Commands with GIS and GEOINT Capabilities

In the UIN infrastructure an effective GIS may be considered because this entity may be the node among the GEOINT entities at the various levels of the Mexican Navy and the link with external GEOINT entities such as other

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[186] "GEOINT Educator; Bringing an Academic Focus to Geospatial Training (Interview with Colonel Stuart Harrison Commandant the School of Geospatial-Intelligence National Geospatial-Intelligence College)," *Military Geospatial Technology,* 7/23/2008, 2008, http://www.military-geospatial-technology.com/article.cfm?DocID=2346 (accessed date 10/7/2008).

[187] Ibid.

governmental intelligence institutions. Failing to do so may result in an inadequate sharing of information among entities and limitations in developing analysis.

In addition, once having the Mexican Navy Intelligence School the capability of specializing intelligence officers in GEOINT may provide the UIN with IAs and GAs who may effectively execute the GEOINT tasks in that unit. In addition, the Intelligence School may prepare GEOINT analysts from the intelligence officers sent by the operational forces. This may provide these forces with professional GEOINT analysts to manage and analyze GEOINT when required.

3.   Action Line: Creation and implementation of LEISA - UIN (Training and Research Lab on Analysis' Software for the Mexican Navy)

LEISA – UIN is the Spanish acronym for *Laboratorio de Entrenamiento e Investigación en Software de Análisis de la Unidad de Inteligencia Naval* (Training and Research Lab on Analysis' Software for the Navy Intelligence Unit).

Nowadays, analytical software has become a tool *sin equa non;* the intelligence analysts are able to develop the complex analysis demanded by the constantly changing environment, which rapidly delivers an enormous amount of information to the intelligence community. Hence, an effective creation and implementation of LEISA-UIN may be the biggest and soundest step for the Mexican Navy in enhancing its GEOINT capabilities.

The main purposes of LEISA-UIN on the training side may be providing training in GIS and other analytical software to the Mexican Navy intelligence community and operational forces and developing a doctrine in digital-data-management. On the research side, the main purposes may be researching on further uses of the current analytical software in the military and intelligence fields, looking for the best analytical software to be used for the Mexican Navy analysts, as well as developing new extensions or models to improve the

analysts' tasks. Hence, LEISA-UIN may play the roles of receiver-filter-provider as well as that of link with other research and educational entities on analytical software.
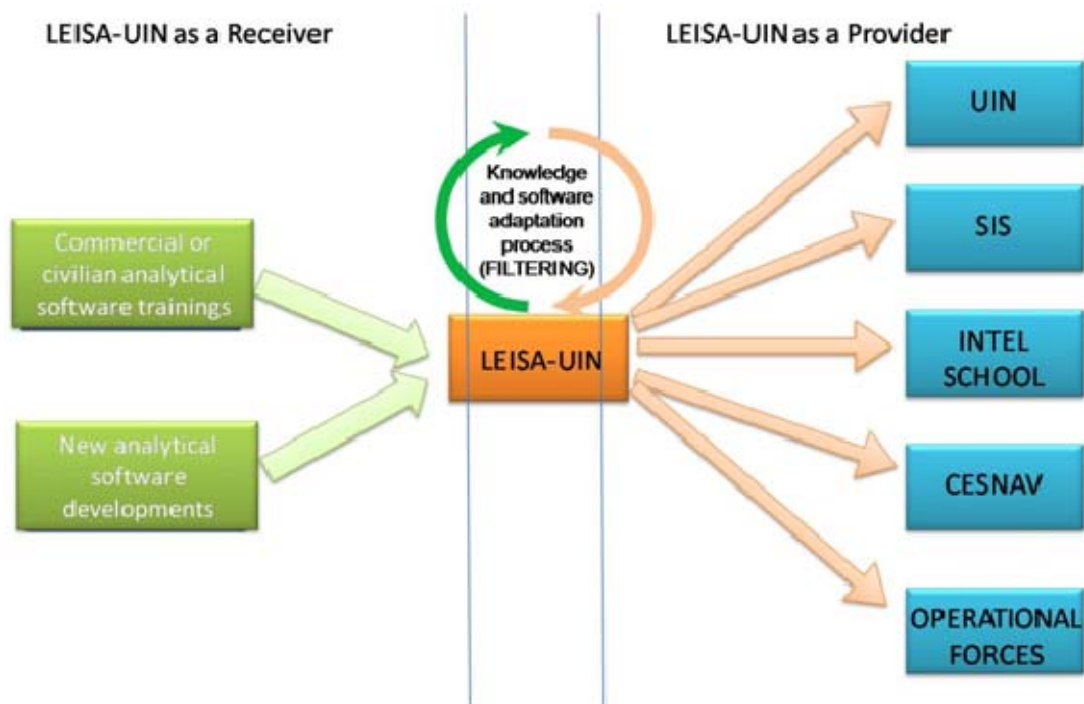
Figure 93.   LEISA-UIN as a Receiver-Filter-Provider

Figure 93 illustrates how LEISA-UIN would act as a Receiver-Filter-Provider. On the receiver's side, it shows different kind of trainings on analytical software offered by commercial or civilian entities to the Mexican Navy. LEISA-UIN instructors analyze these trainings and then they take the ones that the Mexican Navy analysts may require. Also on that side, LEISA-UIN researchers and developers analyze new analytical software developments and take what the Mexican Navy may require. During the filtering process, the LEISA instructors, researchers, and developers adapt the trainings and software development to be applicable to the military and intelligence fields. On the provider's side, LEISA-UIN provides new military and intelligence oriented analytical software

knowledge to the analysts in the different Mexican Navy entities, as well as new software applications that they may require. Figure 94 illustrates the kind of support LEISA-UIN may give to every Mexican Navy entity on the provider's side.

Figure 94.   LEISA as a Provider[188]
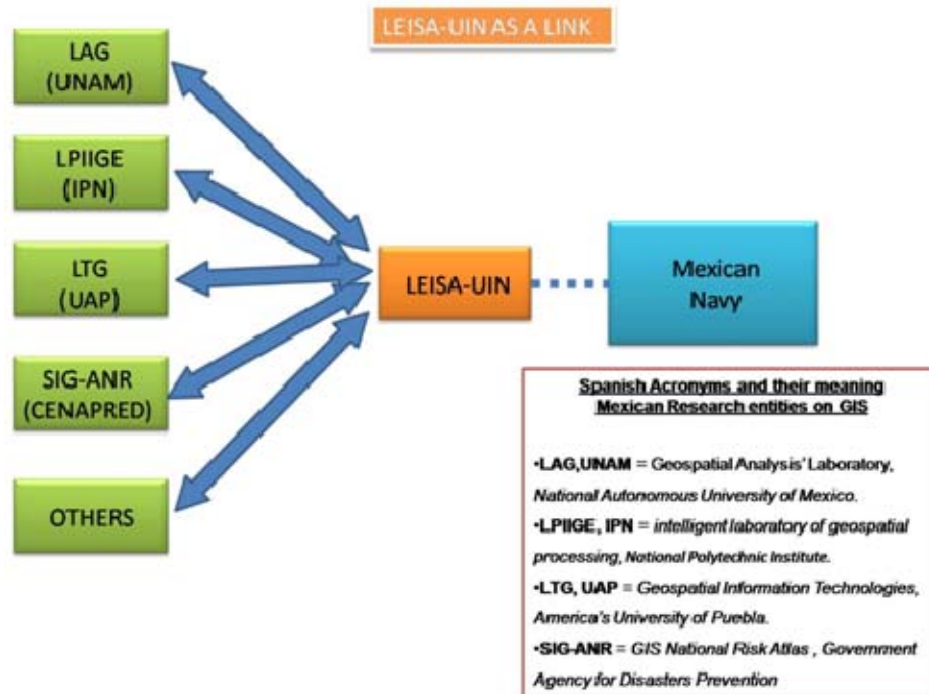
Figure 95.   LEISA as a Link with other research entities

In addition, LEISA-UIN may act as a link between the Mexican Navy and the educational institutions that provide training on analytical software as well as research and development in that field, Figure 95. The purpose of this relationship may be the sharing of new knowledge and findings in analytical software that may benefit each other.

D.   PRELIMINARY APPROACH FOR THE ENHANCEMENT OF THE GEOINT CAPABILITIES IN THE MEXICAN NAVY: PROPOSED STAGES FOR IMPLEMENTATION

In order to know when and to what extent the action lines may be implemented, the author presents this approach as a scalable proposal that may provide the Mexican Navy top-decision-makers with the flexibility to carry it out as the budget, human, and material resources allow. It may be applied completely, by considering all the stages in the project, or partially, by just considering the first stages, which at the same time could also be reduced in scope or size in

concordance with the resources available or authorized. Considering GEOINT centralization as a current problem in the Mexican Navy, Ii is worth mentioning that the more stages the implementation takes, the more decentralized the GEOINT structure will be and consequently the GEOINT capabilities may increase. Hence, the approach was divided in four stages as illustrated in Figure 96.
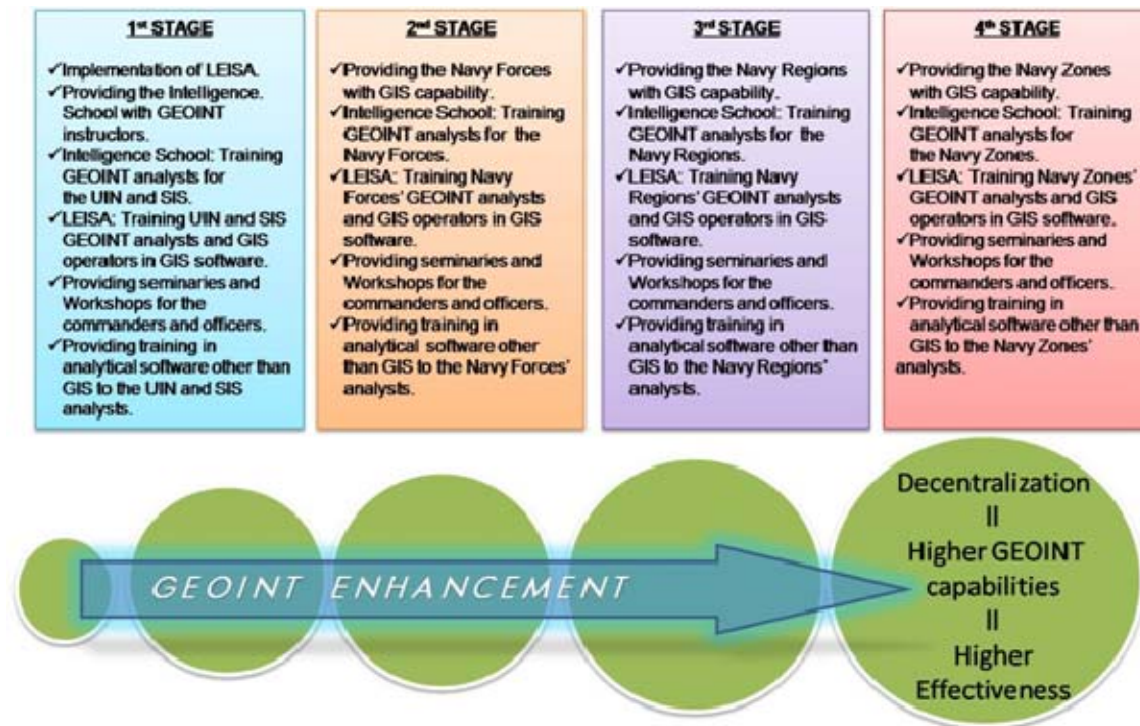
Figure 96.   Stages of the Preliminary Approach for the enhancement of the Mexican Navy GEOINT capabilities

1.   LEISA – UIN First Stage

The first stage of LEISA-UIN may be the cornerstone of the whole project. This stage may provide the platform for the professionalization of the Mexican Navy commanders and other officers in GEOINT as well as a foundation for future implementation of subsequent stages. This stage may consider first the implementation of LEISA-UIN and provide the Intelligence school with IA and GA

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instructors and then LEISA-UIN may train the Mexican Navy analysts on analytical software, and the Intelligence School may train the intelligence officers on GEOINT. LEISA-UIN may also provide workshops and seminaries on analytical software to the decision-makers at different levels.

2.   LEISA – UIN Second Stage

In this stage, the Mexican Navy GEOINT capabilities may increase by providing the Navy Forces with an adequate GIS structure (software and hardware) as well as personnel highly trained by the Intelligence School and LEISA-UIN in GEOINT and analytical software. The increment of Mexican Navy GEOINT capabilities may expand through the decentralization of GEOINT and GIS and the collaboration among the strategic and operational levels.

3.   LEISA – UIN Third Stage

The implementation of this stage is similar to the second one with the difference that the actions taken here are meant to provide the Mexican Navy Regions with GEOINT capabilities. As noted, the more stages implemented, the more GEOINT decentralization will result in the Mexican Navy, resulting in higher GEOINT capabilities and effectiveness.

4.   LEISA – UIN Fourth Stage

The implementation of this stage is similar to the second and third one with the difference that the actions taken here are directed to provide the Mexican Navy Zones with GEOINT capabilities. As established, this preliminary approach is scalable, as such, this stage should not be considered the last one, because in the future the GEOINT capabilities could be extended to lower levels in the Mexican Navy.

E. SOME PROPOSED ASPECTS FOR THE IMPLEMENTATION OF LEISA-UIN

LEISA-UIN creation and implementation would entail the addition of a new organizational structure to the Mexican Navy, one in which the physical installation of systems and facilities support the laboratory. In this section, a few that have to do with planning, training of the instructors and organizational structure, will be pointed out. Conversely, the physical installation of systems and facilities may be part of an exhaustive planning if the implementation of LEISA-UIN is decided by the Mexican Navy.
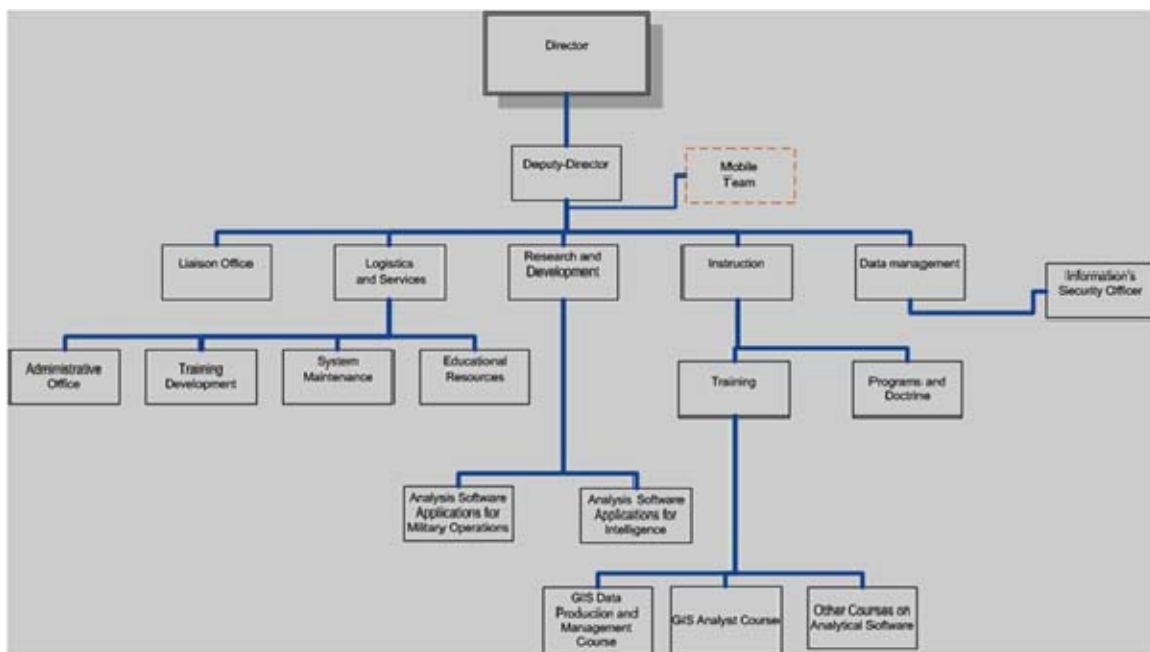
Figure 97. LEISA-UIN Organizational Structure

Figure 97 illustrates the proposed organizational structure for LEISA-UIN. In this preliminary approach, LEISA-UIN may rely on a director as the head of the lab, a deputy director as the second in command and include five sections. The functions of each section and their components will be explained next.

1.   Instruction Section

This is the core of LEISA-UIN and it embraces the "training" and the "programs and doctrine" sub-sections. The training sub-section may be integrated by the instructors on analytical software, who are divided according to the courses that may be offered by this lab.

The "GIS data production and management course" may train Mexican Navy personnel on GIS-software's basic functions as well as on how to produce, integrate, store, manage, and share GIS datasets. This course may provide the GIS data managers with a doctrine to improve the exchange of information among them and GEOINT processes, as well as the task of keeping the GIS datasets and security of information current.

The "GIS analyst course" may train Mexican Navy officers first on the foundations of geography, geospatial analysis, statistics, and analytical methods. Then they may be trained on GIS functions, emphasizing the analytical tools; the analysts may receive the basics on data management so the GIS data-managers and the GIS analysts speak the same language and understand and manage the datasets in the same manner.

Another component of the training sub-section may be related to other analytical software such as those related to network analysis or crime investigation that could be integrated with GIS to multiply the effectiveness of the analysis in the military and intelligence fields.

The second component of the instruction section is "programs and doctrine" sub-section. This sub-section may be in charge of producing and keeping current the instruction programs, as well as generating a doctrine of use to the analytical software.

2.   Research and Development Section

Research and development could be divided in "analysis software applications for military operations" and "analysis software applications for intelligence." This section may be in charge of researching current GIS software and innovations to find their application in the Mexican Navy. It may also develop models, tools, or/and software extensions to facilitate the analyst's work. In the GIS side of this section, their members may take the "GIS analyst course" and an external course on GIS development.

3.   Data Management Section

This section may be in charge of obtaining and preparing the information products required by the training and research and development sections, as well as organizing and managing the information in the lab's computers. In addition, this section may be in charge of establishing the security of information mechanisms and verifying the security of information measures. On the GIS side of this section, their members may know about security of information in the Mexican Navy and they may take the "GIS data production and management course."

4.   Logistics and Services Section

This component of LEISA-UIN may function as the provider of the resources required by the lab to execute its functions. In addition, this section may be responsible for the administrative work and the services in the lab. "System maintenance" may provide the technical support to the network and hardware in the lab. On the other hand, "training and development" may be in charge of managing the resources for funding the training of the instructors and researchers to keep them actualized in analytical software.

5. Liaison Office

This office may establish and maintain the links between LEISA-UIN and other educational institutions as well as research laboratories on analytical software.

6. LEISA-UIN Mobile Team

Mobile team is not an organizational component of LEISA-UIN but a task force or ad-hoc unit that can be integrated by personnel and material resources from the lab. This concept is based, to some extent, on the NGA's Mobile Training Teams (MTTs) that are used to "…deliver training suitable for ranks from military enlisted personnel through senior officers… MTTs arrive at sites completely equipped to teach, even bringing mobile computer labs when necessary."[189]

In this case, the LEISA-UIN mobile team may be deployed not only to deliver training and assessment to the operational forces or other Mexican Navy entities, but also to execute analysis' exercises on the ground with the LEISA-UIN trainees. In addition, the mobile team may provide LEISA-UIN the capability for evaluating analytical software in different geographic areas, with different Mexican Navy units, and in other conditions required to test the software.

7. LEISA-UIN Implementation Sequence

As noted, the development of LEISA-UIN may require exhaustive planning; in this preliminary approach, a proposed sequence will be established that is illustrated in Figure 98.

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[189] "Mobile Training Teams Take GEOINT on the Road," http://www1.nga.mil/Newsroom/Pathfinder/0604/Pages/MobileTeams.aspx (accessed date 10/7/2008).
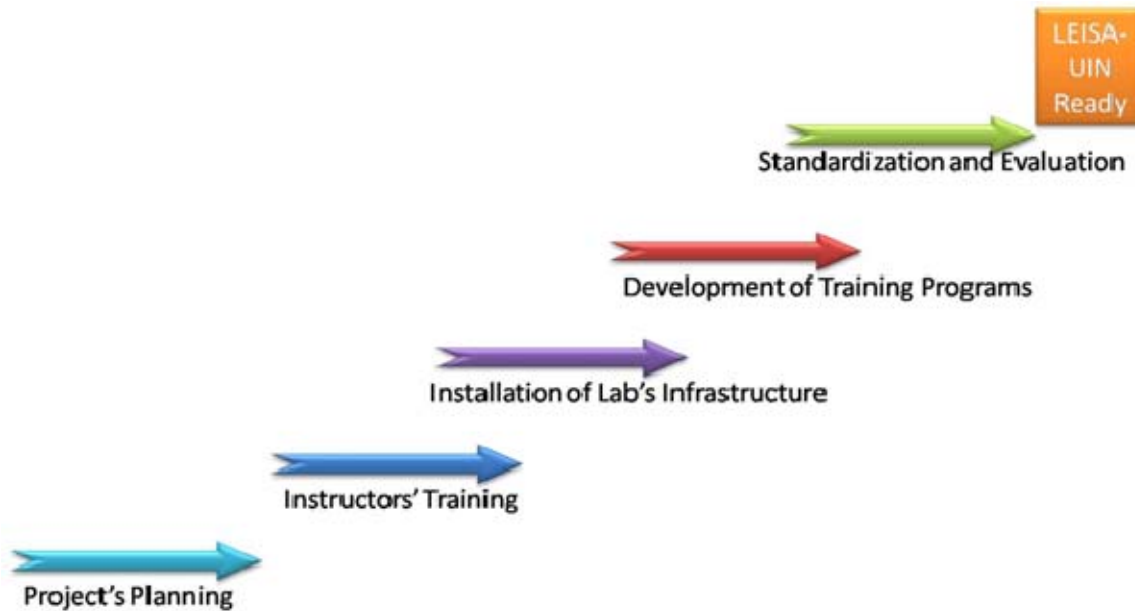
Figure 98.   LEISA-UIN implementation sequence

The first and most significant step of LEISA-UIN implementation may be the project's planning, which may initiate with the establishment of a team composed of people from the following fields: GIS, GEOINT, intelligence, information systems, security of information, computer and communication networks, education, administration, and logistics. It is recommended that these people be chosen from the Mexican Navy people; even if some of them will not need to rely on the required knowledge. Preparing them in their related field may be preferable to hiring a consultant to do the work. This is because the consultant may not always be part of the Mexican Navy, and in the future, Mexican Navy people may be the ones who deal with LEISA-UIN issues. A GIS consultant could be hired but for assessment purposes only. As Tomlinson notes

> Some organizations attempt to circumvent the knowledge gap by hiring consultants to operate the GIS, under the assumption that these "hired guns" will bring the needed knowledge into the company… Hiring a consultant is just another way of buying the

skills you really need in your organization. It is a short-term solution
to what may be a long-term requirement.[190]

The project's team may collaborate to create a LEISA-UIN scheme that
considers the estimated number of people who need to be trained in a given
period, institutional interaction requirements, system requirements and data
sharing, security issues, existing computing environment, migration strategy, risk
analysis, system maintenance, as well as staff's, instructors', researchers',
managers, and technicians' training regime.[191]

When the plan is finished and approved by the top decision makers the
next series of steps could be taken. Subsequent steps may or may not overlap
without affecting the process. The first step, after the planning may be sending
the instructors, researchers and other required people to train in their field of
competence, and once prepared, these people may be certified by the Mexican
Navy educational system. The next step may be installing the lab infrastructure
that embraces the facilities and other material resources, hardware, networks,
and software required for an effective operation of LEISA-UIN. Staff and
instructors then may develop the training programs that may be taught in the lab.
The last step may be the evaluation of the programs and the standardization of
knowledge among the instructors, managers, and developers so that they may
speak the same GIS language and this may contribute with the establishment of
a GIS doctrine.

Because the Mexican Navy already counts on GEOINT capabilities as well
as the fact that it has a very well established intelligence-system-network that
ranges from the strategic to the tactical level, enhancing the GEOINT capabilities
of the Mexican Navy may not be a complex task. However, the magnitude of the
approach here presented cannot be completed overnight; a competitive team,

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[190] Tomlinson, *Thinking about GIS; Geographic Information System Planning for Managers*,
169-170.

[191] Ibid., 168.

the required resources, as well as the support of the top decision makers are crucial for success in this demanding task that certainly may result in increasing the effectiveness of that institution.

VI.   CONCLUSION

It has become appallingly obvious that our technology has exceeded our humanity.

Albert Einstein

Since the advent of humans on the surface of earth, geography has been a part of their thinking. Immanuel Kant's three ways of thought would agree with this statement in that he refers to the idea that when people reason about a situation, they relate it to its nature or Topic, as well as to Time and Space. To that end, "space" as a dimension *sin equa non,* makes it possible for the military to execute an operation; hence, since ancient times, militaries have used maps or terrain models for the planning, command and control of their battles and missions.

Nowadays, the advent of new technologies such as GPS and GIS have allowed the military and intelligence fields to rely on precise situational awareness, as well as to develop complex analyses with large amounts of data in order to support commanders in their quest to make effective decisions without wasting valuable time and resources. Doing this successfully with the use of GIS would appear to be a luxury for a military institution that completes an effective job without the use of GIS. However, no longer can such technology be seen as a luxury but rather it is a necessity for any military, and the Mexican Navy is included. This work has offered many reasons to justify this statement; however, just the most important ones will now be highlighted. First, targets have become faster and more flexible. Second, technology is now available for criminal organizations that can afford it. Third, because of the enormous amounts of intelligence available for analysts, it is almost impossible to analyze this information effectively, without having adequate information system's tools. Finally, most of the Mexican government institutions and many other agencies,

companies, and educational institutions have taken advantage of the benefits of GIS, and the Mexican Navy should be able to rely on an adequate GIS capability in order to share information and knowledge among these entities, also.

In order to incorporate GEOINT in Mexico it is necessary to make the most of its three components: imagery, IMINT and geospatial analysis. This is because Mexican armed forces appear to be based on visualization alone with an inclination for IMINT and imagery while ignoring geospatial analysis. In that regard, is worth noting that geospatial analysis is a powerful component that has the ability to combine large amounts of geospatial data that could provide an analyst with valuable information products. These information products could include risk maps, geospatial patterns and the visualization of attributes of the factors involved in the problem to be analyzed.

 GEOINT may be considered as a part of the intelligence mainstream, as well as "a part of" and "complement from" the other intelligence disciplines, such as HUMINT, SIGINT, MASINT, and OSINT. Hence, in developing the GEOINT process, the analysts may follow a methodology that considers the workflow in concordance with the intelligence mainstream such as the GEOINT-process-model presented in this thesis. This may facilitate sharing of information among intelligence and/or military entities with the consequence of saving time, as well as human and material resources.

As we know, GIS analytical software –such as ArcGIS, which is mainly used by the intelligence and military institutions, in particular the Mexican Navy– has a variety of applications in the intelligence and military fields. This software can be used within the entire spectrum of military and intelligence operations such as NSA, signal propagation (communications), training, command and control, as well as sea, land, and air military operations. Furthermore, GIS has the ability to support, in one way or another, a broad spectrum of military and

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intelligence operations from the strategic down to the tactical level, inclusive. This makes GIS an essential support for the decision making process in the Mexican Navy.

However, it is worth noting, that the software cannot deliver precise results by itself, nor will it replace the knowledge and experience of decision makers. Hence, on the one hand, the potential GEOINT analysts may not just need ArcGIS to complete GEOINT analysis; they will also need knowledge in the intelligence and military fields as well as adequate training in the use of ArcGIS. On the other hand, the military decision makers will certainly need to know about the capabilities of the analytical software as well as the ability of the GEOINT analysts under their command in order to make critical decisions. Hence, in the case of the Mexican Navy, utilizing GEOINT means the integration of an adequate GIS network structure integrated by analysts, software, and hardware, as well as the capability of training analysts in GEOINT applications in the intelligence and military fields with relative independence from commercial training, which focuses on other fields.

In addition, tasks in the everyday performance of the Mexican Navy operational forces require timely coordination and effective-decision-makers' responses; however, due to the fact that Mexican Navy tasks are many and diverse, Mexican Navy operational commanders face a large endeavor when it comes to analyzing and solving the implicit problems brought into play. The lack of timely and accurate decisions in solving these problems could lead to a waste of human and material resources.

Hence, understanding GEOINT and its process and knowing about the multiple GIS applications in the military and intelligence field contained in this work is a good first step for the Mexican Navy analysts. In addition, to make effective use of this GIS and GEOINT, some actions should be taken by the Mexican Navy. These actions are based on the importance of GEOINT and GIS as well as on the current status of the GEOINT in this institution, which is

currently concentrated within the General Staff creating a consequent work overload for the General Staff that is based primarily on imagery and IMINT visualization. Hence, the actions recommended in this thesis include:

- Providing the Mexican Navy Intelligence School with GEOINT instructors.

- Providing the UIN and operational commands with GIS and GEOINT capabilities.

- Creation and implementation of a Training, Research, and Development Lab in analytical software for the Mexican Navy (LEISA-UIN).

These three actions, for which the preliminary approach for implementation was presented in chapter V, if implemented by the Mexican Navy, could enhance its GEOINT and GIS capabilities exponentially. Consequently, the implementation of a project for enhancement of the Mexican Navy GEOINT capabilities, based on this preliminary approach, may have the following purposes and benefits:

- Consolidation of the GEOINT structure, which at the same time may contribute to the consolidation of the entire intelligence system and sharing of information.

- Professionalization of the GEOINT community in the UIN, SIS, and operational forces, and at the same time providing a platform for professionalization of the decision makers in information systems.

- Military oriented training, research, and development on information-systems, resulting in an evolving military institution, which is less dependent on commercial trainings, assessments, and software tools that potentially contribute to wasting money and resources in non-military-related issues.

- Providing the Mexican Navy officers with the support of computational resources and assessment for their thesis work or other research as related to the field of information systems.

- Taking the lead on GEOINT in Mexico on the military side of geospatial analysis, ultimately providing competitiveness with other institutional and educational research-and-development entities in Mexico.

- Providing a sound platform of information sharing with other Mexican institutions.

- Relying on the capability of providing expertise assessment in GEOINT, military-geospatial-analysis, and other military-related information systems.

- Providing the operational commanders (Navy forces, regions, and zones) with the flexibility for developing their own analyses, and intelligence based on actual situations within their jurisdiction, taking into account the capabilities and constraints of their available forces.

- Relieving the SIS from tasks that are not the essence of its existence.

- Providing a GEOINT and GIS doctrine in the Mexican Navy.

The enhancement of GEOINT and GIS in the Mexican Navy may contribute to an improvement of its overall performance and the effectiveness of the Mexican Navy, as well as provide commanders with the support needed to act in a more proactive way. This may also contribute, in the near future, in raising the Mexican Navy to the same level as other governmental or educational institutions that already rely on GIS.

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APPENDIX DETAILS OF SOME GEOSPATIAL-ANALYSIS OPERATIONS DEVELOPED IN THE SCENARIO PRESENTED IN CHAPTER IV

The purpose of this appendix is to provide further information about the development of the GEOINT analysis found in chapter IV. Hence, this appendix is meant for the reader who has certain knowledge of geospatial analysis.

A. TECHNICAL DETAILS OF THE DIGITAL INFORMATION PRODUCTS THAT CONSTITUTE THE "RAW DATASET" OF THE GEOINT ANALYSIS PRESENTED IN CHAPTER IV

The files required for the GEOINT analyst that constitute the "raw dataset" for the analysis include:

a. a. Digital georeferenced topographic map E14c46 "Coyuca de Benitez," scale 1/50000 in TIFF or PDF format.

b. b. Digital georeferenced topographic features for map E14c46 "Coyuca de Benitez," scale 1/50000: Roads and paths, villages, bodies of water, and vegetation.

c. c. Digital Elevation Model (DEM) of the E14c46 area.

d. d. Recent satellite and aerial images of the E14c46 area.

e. e. Digital georeferenced topographic map E1407 "Zihuatanejo," scale 1/250000 in TIFF, GIF, PDF, or IMAGINE format.

f. f. Digital georeferenced topographic map E1408 "Chilpancingo," scale 1/250000 in TIFF, GIF, PDF, or IMAGINE format.

g. g. Digital georeferenced topographic map E1411 "Acapulco," scale 1/250000 in TIFF, GIF, PDF, or IMAGINE format.

B.   CREATION OF A POINT FEATURE CLASS FROM A TEXT FILE WITH ARCGIS FOR PURPOSES OF THE GEOINT ANALYSIS PRESENTED IN CHAPTER IV

The GEOINT analyst creates a point feature class containing the location of the recon patrol to be rescued (Objective) as well as one with the four enemy observation points (En_Obs). He does so by writing the UTM coordinates in a text file (Notepad) after which he runs the ArcGIS tool of *Samples> Data Management> Features> Create Features from Text File.* The input text needs to be written in a specific format so that the software can read the file:

Point
0 374788.22619 1902721.92857 ────── This is the text for the Objective.
END

Point
0 381116.877971 1901151.67221
1 383733.791943 1904983.58195 ──── This is the text for the "Enemy observation points."
2 380602.841298 1906432.23076
3 377985.927326 1901432.05585
END

The first line contains the geometry type of the shapefile; the next lines may be "*id* **space** *X coordinate* **space** *Y coordinate*." The final line must contain the word *END*.

C.   GEOREFERENCE SYSTEM USED IN THE GEOINT PROCESS PRESENTED IN CHAPTER IV

The system used in the GEOINT process is the following:

Geographic Coordinate System: GCS_North_American_1927

Angular Unit: Degree (0.017453292519943299)

Prime Meridian: Greenwich (0.000000000000000000)

Datum: D_North_American_1927

Spheroid: Clarke_1866

D. MOSAIC DEVELOPMENT BY MEANS OF ARCGIS FOR PURPOSES OF THE GEOINT ANALYSIS PRESENTED IN CHAPTER IV

In the task of "Process data," which is part of the "processing and exploitation" step, the GEOINT analyst built a first mosaic with the three digital maps scale 1/250000 by means of the Data Management Tools> Raster> Raster Dataset> Mosaic tool. However, when the mosaic tool was used, it did not work properly with the maps available for the analysis (paper maps scanned and georeferenced) that constitute the dataset; as a result, the final mosaic was blurred in some parts and had a variety of tones in others, Figure 99. Therefore, the analyst decided to use the Data Management Tools> Raster> Raster Processing> Clip tool instead. This tool allowed for the cutting of the borders of the maps so that they can fit together in a way similar to a jigsaw puzzle, Figure 100.
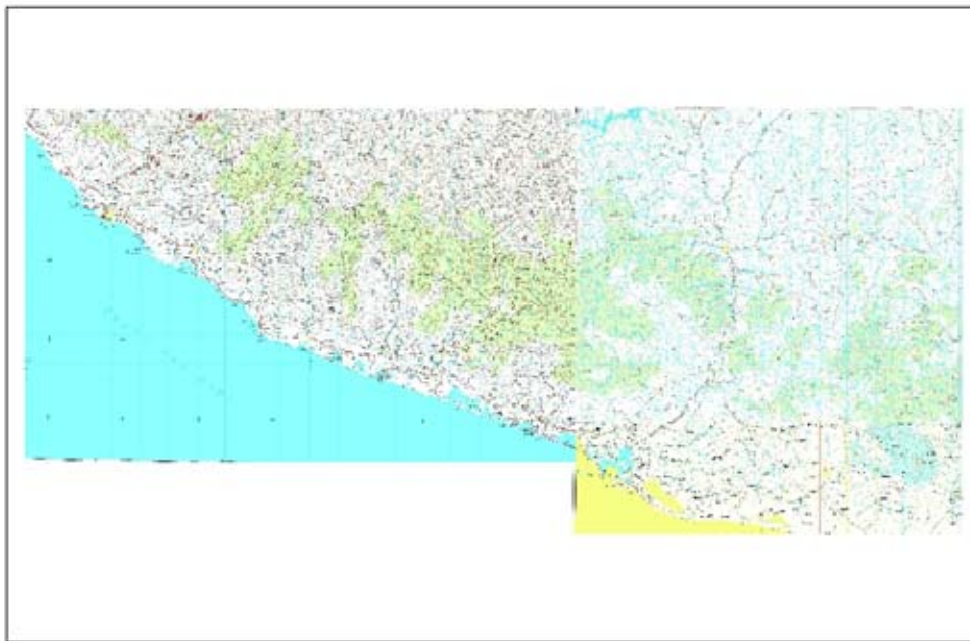
Figure 99.   Mosaic built with ArcGIS mosaic tool (blurred)

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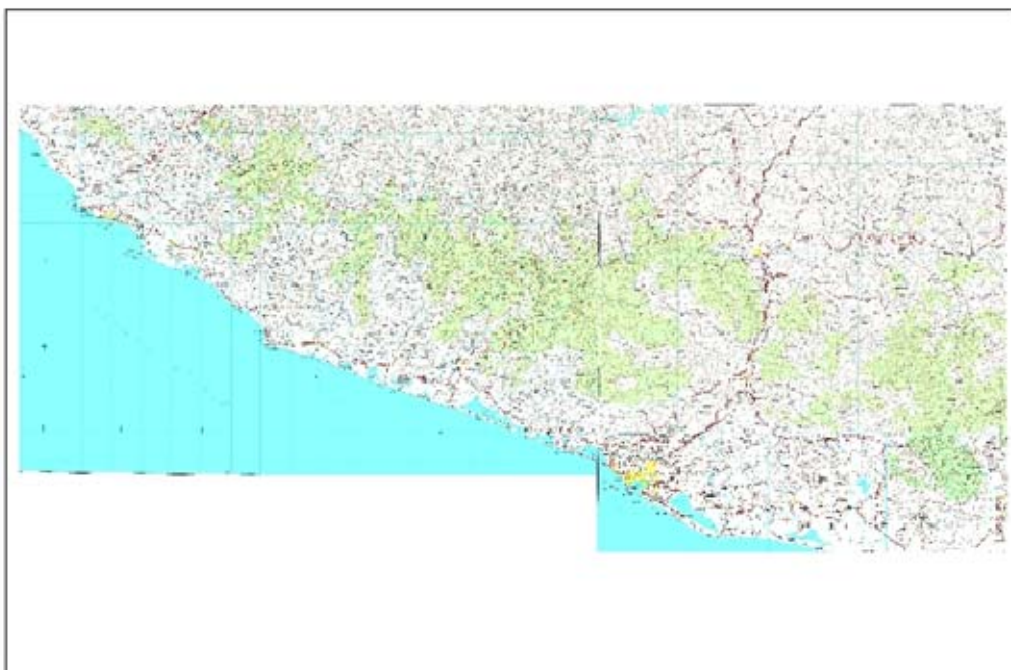
Figure 100. Mosaic built by clipping the digital maps

E. DEVELOPMENT OF A MODIFIED-SWISS-STYLE HILLSHADE FOR PURPOSES OF THE GEOINT ANALYSIS IN CHAPTER IV

To create the base-map in order to represent the different features required for the GEOINT analysis, a modified-Swiss-style-hillshade is developed. This is basically a combination of hillshades that provide a more realistic, less sharpened surface, and more attractive base-map than the standard hillshade. The modified-Swiss-style-hillshade is basically a Swiss-style hillshade that was developed by ESRI[192], with some minor modifications for purposes of this work.

The first step for creating the modified-Swiss-style-hillshade is to execute the following map algebra expression in ArcGIS: HILLSHADE (FOCALMEDIAN (<DEM>, Circle, 6)). This expression is applied to create a hillshade by means of the focalmedian tool to soften the sharps often present in the standard

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[192] Liana Edmiston, Chris Belson and Walt Rennick, *Working with ArcGIS Spatial Analyst for Geospatial Intelligence (GEOINT); Course Exercises*, 2.2nd ed. (Redlands, CA: ESRI educational services, 2005), 8_7-8_10.

hillshades. Consequently, to eliminate these sharps, the focalmedian function writes the median value of the input raster (DEM) within the neighborhood to the output cell of the output raster. This function also emphasizes changes on the surface, allowing the GEOINT analyst to detect them through visualization.

Next, another hillshade is created that is derived from the map algebra expression "<DEM> / 5 + <std_hillshade>." As a result, the second hillshade emphasizes the higher elevation, because a fifth part of the elevation to the standard hillshade was added. The different hillshades and the final modified-Swiss-style are illustrated in Figure 101. It is worth mentioning that the increment applied to the elevation is for visualization purposes only, and will not affect the subsequent calculations made by the GEOINT analyst during the analysis, because they will be based on the original DEM. After that, a ramp color is assigned to the DEM, and the two hillshades are combined with it in order to create the modified-Swiss-style.
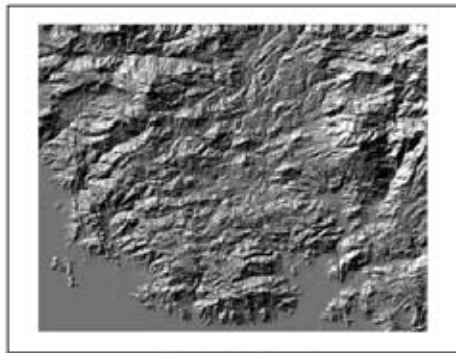
Standard Hillshade
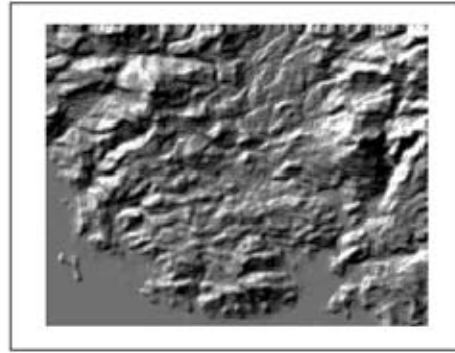
Focal Median Hillshade 35% transparency
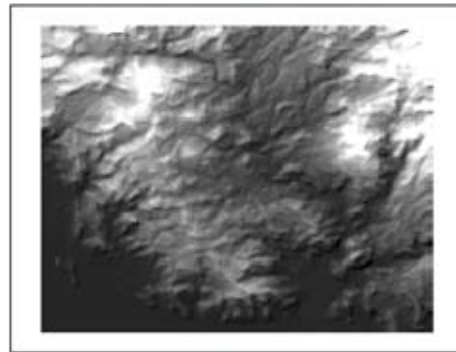
Weighted Elevation Hillshade

Digital Elevation Model with color ramp and 55% transparency

Legend

High : 1900

Low : 3

Modified-Swiss-Style that resulted from the combination of the Focal Median and the Weighted Elevation hillshades with the DEM

Figure 101.   Different hillshades and the Modified-Swiss-Style hillshade

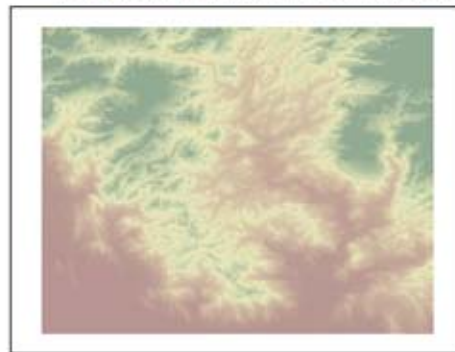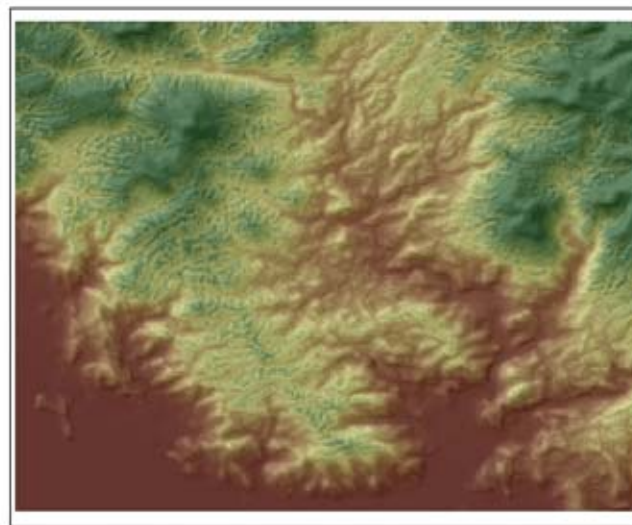## F. REPRESENTATION OF DEMILITARIZED ZONES BY MEANS OF ARCGIS FOR PURPOSES OF THE GEOINT PROCESS PRESENTED IN CHAPTER IV

The representation on the map of the demilitarized zones is made possible by the ArcGIS Analysis> Proximity> Buffer or Multiple rings buffer tools. The input for these tools is the shapefile with the point feature; in this case, the point feature class with *Tepetixtla's* geographic position and the radio of the circle or circles to be created, which in this case are 4000 m for the ground zone and 6500 m for the airspace zone. Figure 102
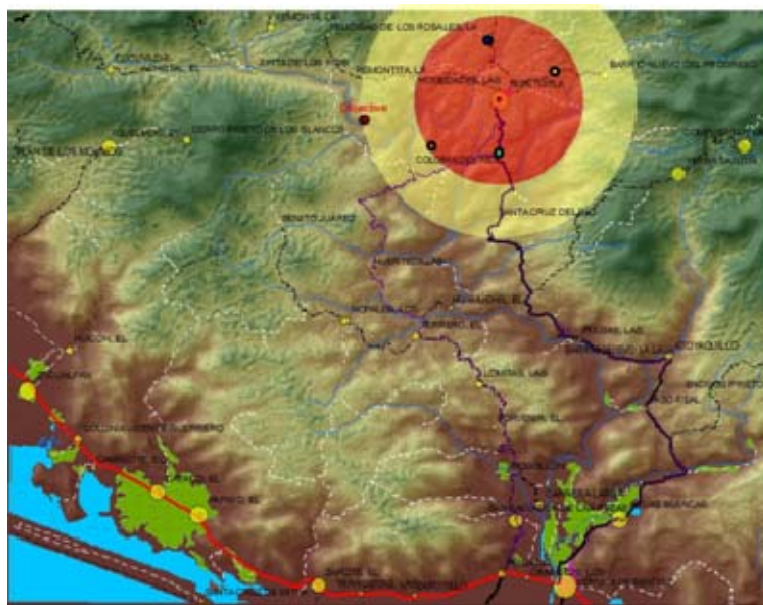
Figure 102.   Map showing the buffers that constitute the demilitarized ground zone (red) and the demilitarized-fly-over-zone (yellow)

G. DIGITAL INFORMATION PRODUCTS THAT CONSTITUTE THE DATASET FOR THE SECOND GEOINT CYCLE IN THE ANALYSIS PRESENTED IN CHAPTER IV

p.   GEOINT dataset produced in the first GEOINT cycle.

q.   Digital georeferenced topographic features of power lines for map E14c46 "Coyuca de Benitez," scale 1/50000.

H. CREATING AN EQUIVALENT SCALE OF VALUES OF VARIOUS FEATURES TO BE COMBINED THROUGH OVERLAYING IN ARCGIS TO CREATE THE SUITABILITY MAPS FOR THE GEOINT ANALYSIS PRESENTED IN CHAPTER IV

When one is combining layers mathematically, in order to get risk-maps or suitability-maps, the values of the features or the pixels of the raster surfaces in the different layers to be combined must be equivalent. For example, in this scenario a layer of slopes, which values are giving in degrees, will be mathematically combined with a layer of dense vegetation, which values are 1 for the parts of the surface where there is dense vegetation and 0 or <null> for parts where there is not, so these two features have different measurement units.

The required equivalence is obtained through classifying the values of the features on a scale of suitability by assigning, respectively, the highest and the lowest values on the scale to the best and worst value in the feature. In this regard, ESRI recommends the use of a scale of 0 to 9 where 0 is "no value," 1 is the "worst," and 9 the "best."[193] This needs to be done with every layer in order to develop the geospatial analysis, in this case.

First, the GEOINT analyst creates a map with the slopes of the surface given in degrees by using the Spatial Analyst> Surface> Slope tool, Figure 103; then the symbology tab from the layer properties is used to get 9 classifications, Figure 104. Next, the slope feature is reclassified by means of the Spatial Analyst> Reclass> Reclassify tool, giving the value of 9 to slopes from 0 to 5 degrees, since the minimum established by the SOF commander was 5, Figure 105.

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[193] Liana Edmiston, Chris Belson and Walt Rennick, *Working with ArcGIS Spatial Analyst for Geospatial Intelligence (GEOINT); Course Exercises*, 2.2nd ed. (Redlands, CA: ESRI educational services, 2005), 10_16.
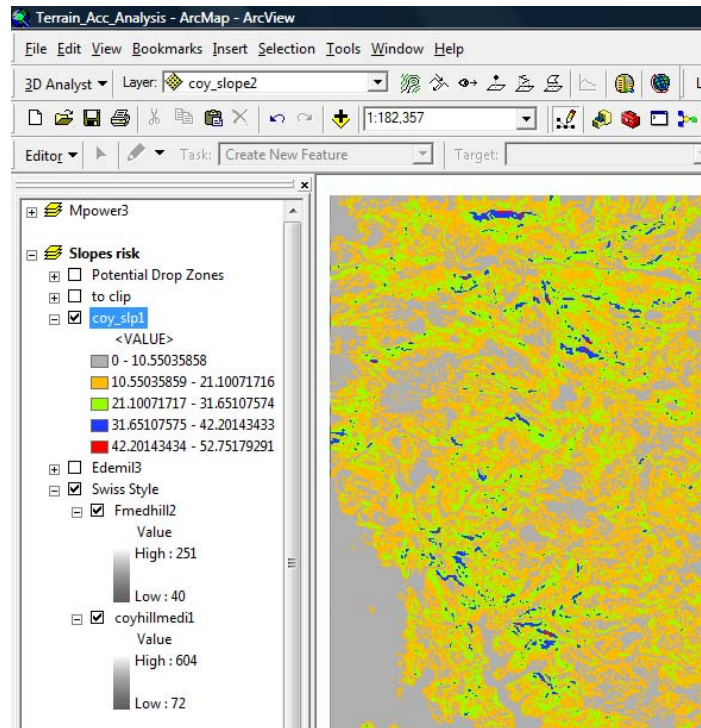
Figure 103. Slopes representation of the area of operation, the table of contents (right window) shows that it has initially 5 classifications in intervals of about 10.5 degrees
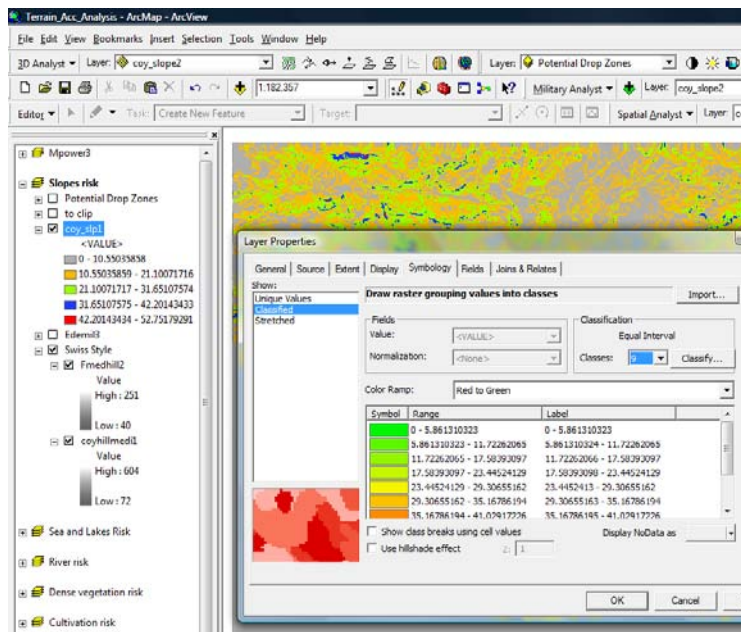
Figure 104. Assigning 9 classification to the slopes feature by means of the layer properties> simbology tab
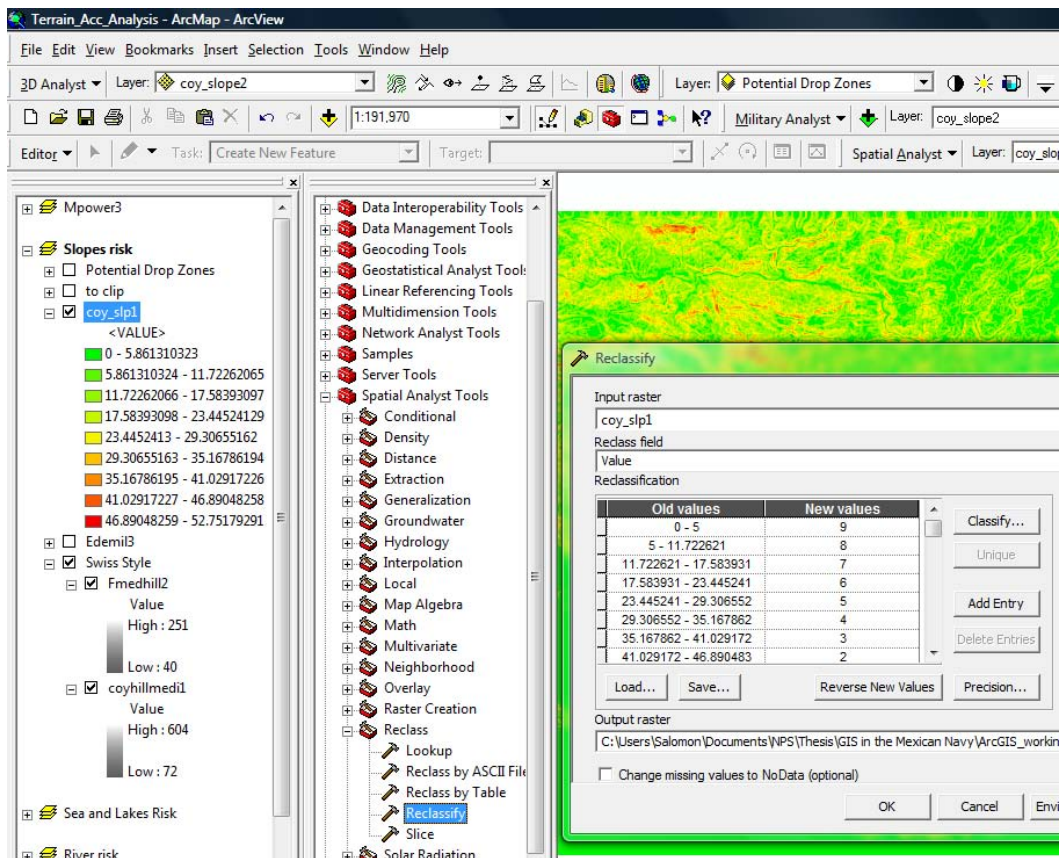
Figure 105. Reclassifying the slopes feature to give it values from 1 (worst value/steeper slopes) to 9 (best value/ less steepness)

It is worth mentioning that there are different ways to map only the "slopes < = 5." For example, by applying map algebra with the conditional (CON) expression "<output raster> = CON (<slope raster> LE 5, 1, 0)"-- this expression means that the "if" the cell value in the slope raster is less or equal (LE) to 5, the new cell value is going to be 1; otherwise the value will be 0. However, because it will be necessary to do the mathematical combination with other layers later, the slope needs to be re-classified as first explained.

For the other features, the GEOINT analyst develops a reclassification that is different from the previously described, because all of the remaining features in this category have considered the distances established in the criteria. This means that the nearer the forces are to the feature, the more risk

they would be taking. To provide these distance measures, ArcGIS relies on the Spatial Analyst> Distance> Euclidean Distance tool; it provides a generic scale of distance from features where the analyst is able to assign a given number of classifications (9 in this case). Nevertheless, when trying to get a precise increment of the distance map, algebra must be developed besides Euclidean distance. This is done by introducing the result received from the Euclidean distance operation and multiplying it by the factor of increment. The map algebra expression to use is "1 + (<factor of increment> * <Euclidean distance to the feature>)."

However, in order to use the map algebra model, one must first find the "factor of increment." Once the equivalence to the best value (9) is known, a single math modeling operation will provide the factor of increment, which is based on a linear equation of suitability –which is based on the linear algebra approach to get a slope– where Suit= a + (b * c). In this equation, it is understood that "Suit" may take the value of 9 (best value in the classification), **a** is the value of 1 (worst value of the classification), **b** is the factor of increment (math slope) for which we search, and **c** is the best suitability value of the feature when the classification receives the value of 9.[194] This operation will be illustrated later in this section.

In this regard the GEOINT analyst takes the power_lines feature class, which is a vector map that represent the power lines in the area of operations, as input and executes the Spatial Analyst> Distance > Euclidean Distance tool, and he calls the output <disttopowerlines>, Figure 106.

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[194] Liana Edmiston, Chris Belson and Walt Rennick, *Working with ArcGIS Spatial Analyst for Geospatial Intelligence (GEOINT); Course Exercises*, 2.2nd ed. (Redlands, CA: ESRI educational services, 2005), 10_17.

Hillshade with power_lines feature class

Hillshade with power_lines feature class and its Euclidean distance (disttopower)

Figure 106.   Euclidean distance to power lines

Once the raster with a generic Euclidean distance is known, the GEOINT analyst needs to obtain the factor of increment through the suitability equation, according to the minimum established by the SOF commander (500 m).

Suit= a + (b * c)

9 = 1 + (b * 500)

b= (9 − 1) / 500 = 8/500

b= 0.016 = factor of increment

Figure 107 illustrates the equation for the linear suitability function.
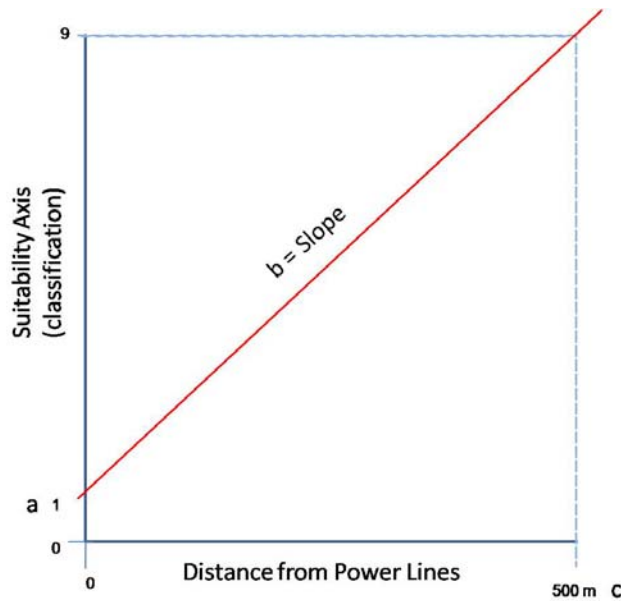
Figure 107. Graphic representation of the equation for the linear suitability function[195]

Once the factor for power lines (0.016) is known, map algebra is used to get a raster that will map the desired increments.[196] In this regard, the following function is executed, first "Mpower1= 1 + (0.016 * disttopower)" Figure 108. This expression applies the desired increment to every cell of distance to the output, which is Mpower1.

[195] Liana Edmiston, Chris Belson and Walt Rennick, *Working with ArcGIS Spatial Analyst for Geospatial Intelligence (GEOINT); Course Exercises*, 2.2nd ed. (Redlands, CA: ESRI educational services, 2005), 10_17.
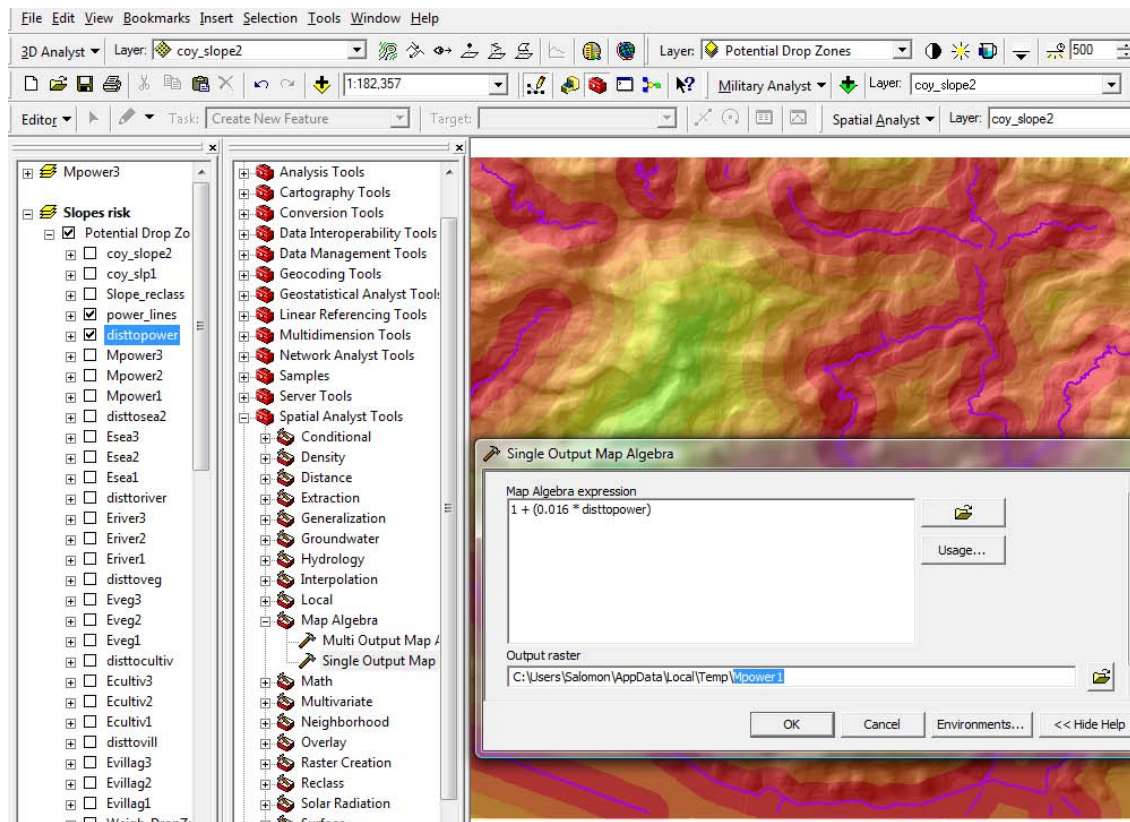
[196] Ibid., 10_18.

Figure 108. Using map algebra to get Mpower1 when working with the power lines feature

Next, the values > 9 will be set to 9, since this is the value chosen as the best; consequently, every cell with higher values fits in this classification. This is obtained by means of the expression "Mpower2= CON (Mpower1 GT 9, 9, Mpower1)." This expression means that if the value of the input cell is > 9 then the output cell will be 9; otherwise, the cell will retain its original value.

Mpower2 is a raster with "floating points"; these points are values with decimal numbers, which need to be converted to integers because the tools to be used in later steps (weighted overlay) only accept integer values. The map algebra expression to use is "Mpower3= INT (Mpower2 + 0.5)," where the map algebra function adds 0.5 to the input cell value and then the INT function rounds it to get an integer value. The result (Mpower3) is the power-lines risk map, Figure 109.

Figure 109. Power Lines Risk Map (Mpower3)

The remaining features of the Terrain and accessibility category are analyzed in the same way as the power-lines feature to get the risk-maps, also known as suitability maps. To avoid repetition of the processes in this work, only the parameters, inputs, and outputs will be presented for all of them.

Feature: Sea and Lakes

- Minimum suitable distance from feature: 500 m
- Input for getting the Euclidean distance: wa_rast_datas
- Output from the Euclidean distance function: disttosea2
- Factor of increment from the linear suitability function: 0.016
- Msea1: 1 + (0.016 * disttosea2)
- Msea2: CON (Msea1 GT 9, 9, Msea1)
- Msea3 (Sea and Lakes risk map; output): INT (Msea2 + 0.5)

Feature: Rivers

- Minimum suitable distance from feature: 100 m
- Input for getting the Euclidean distance: Rivers
- Output from the Euclidean distance function: disttoriver1
- Factor of increment from the linear suitability function: 0.08
- Mriver1: 1 + (0.08 * disttoriver1)
- Mriver2: CON (Mriver1 GT 9, 9, Mriver1)
- Mriver3 (Rivers risk map; output): INT (Mriver2 + 0.5)

Feature: Dense Vegetation

- Minimum suitable distance from feature: 100 m
- Input for getting the Euclidean distance: dens_veg_ras
- Output from the Euclidean distance function: disttoveg2
- Factor of increment from the linear suitability function: 0.08
- Mveg1: 1 + (0.08 * disttoveg2)
- Mveg2: CON (Mveg1 GT 9, 9, Mveg1)
- Mveg3 (Dense Vegetation risk map; output): INT (Mveg2 + 0.5)

Feature: Cultivation Areas

- Minimum suitable distance from feature: 100 m
- Input for getting the Euclidean distance: e14c46ra
- Output from the Euclidean distance function: disttocultiv
- Factor of increment from the linear suitability function: 0.08
- Mcultiv1: 1 + (0.08 * disttocultiv2)
- Mcultiv2: CON (Mcultiv1 GT 9, 9, Mcultiv1)
- Mcultiv3 (Cultivation Areas risk map; output): INT (Mcultiv2 + 0.5)

Feature: Villages

- Minimum suitable distance from feature: 100 m
- Input for getting the Euclidean distance: Villages_extent
- Output from the Euclidean distance function: disttovill
- Factor of increment from the linear suitability function: 0.08
- Mvillag1: 1 + (0.08 * disttovill)
- Mvillag2: CON (Mvillag1 GT 9, 9, Mvillag1)
- Mvillag3 (Villages risk map; output): INT (Mvillag2 + 0.5)

The GEOINT produced in the category of Terrain and accessibility is illustrated in Figure 110.
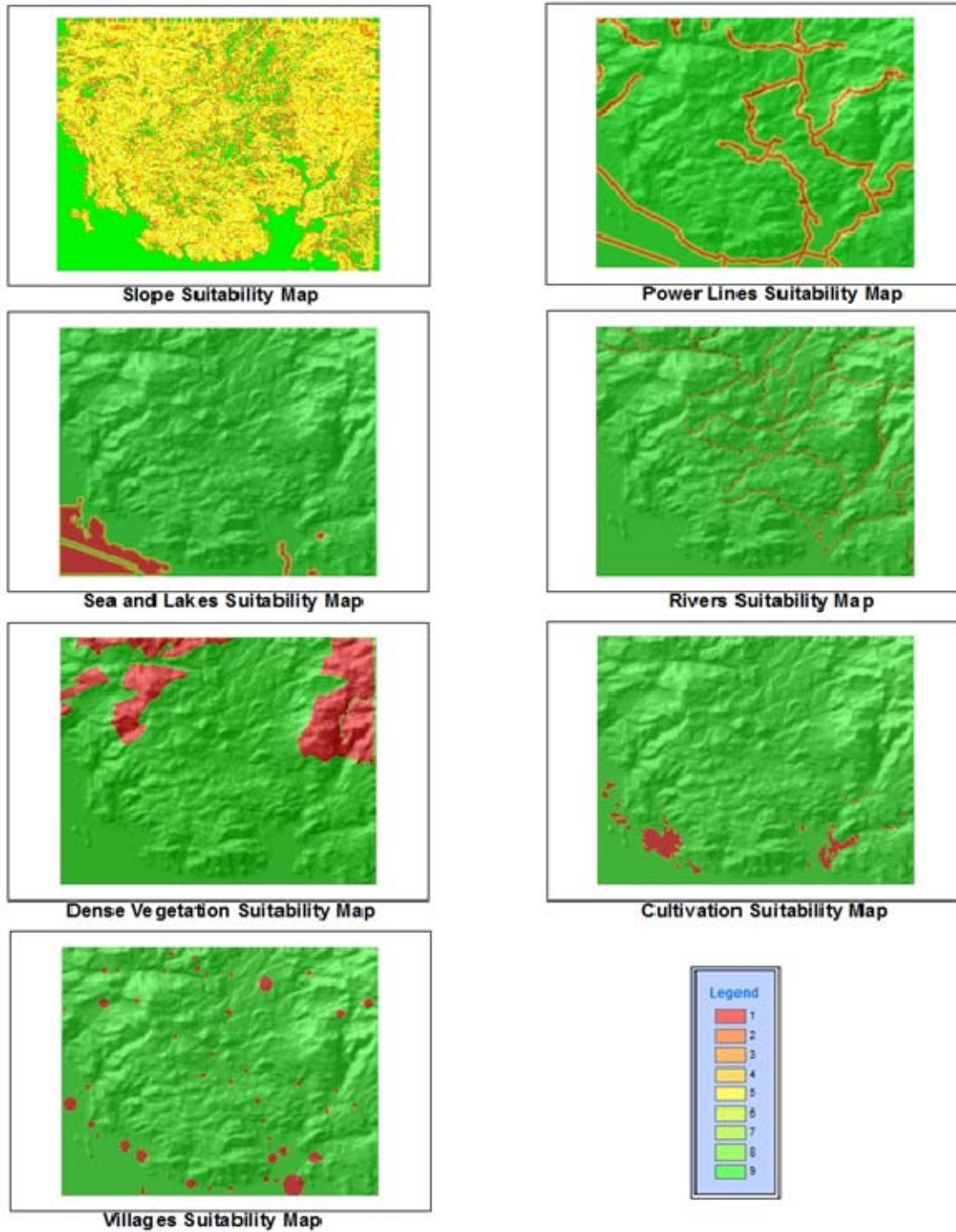
Figure 110.   Terrain and Access Risk Suitability Maps; 9 = Best (green), 1 = Worst (red)

I. HOW TO CREATE A WEIGHTED OVERLAY WHEN WORKING WITH SUITABILITY MAPS FOR PURPOSES OF THE GEOINT PROCESS PRESENTED IN CHAPTER IV

When overlaying features to get suitability maps there are usually some features which are more important than others , and the Spatial Analyst> Overlay> Weighted Overlay tool allows the analyst to weight the layers (features) according to their importance. Therefore, in this regard, the SOF commander has asked for this in percentage values, which means that the sum of the percentages of the seven layers must be 100%. The values assigned are presented in Figure 111.
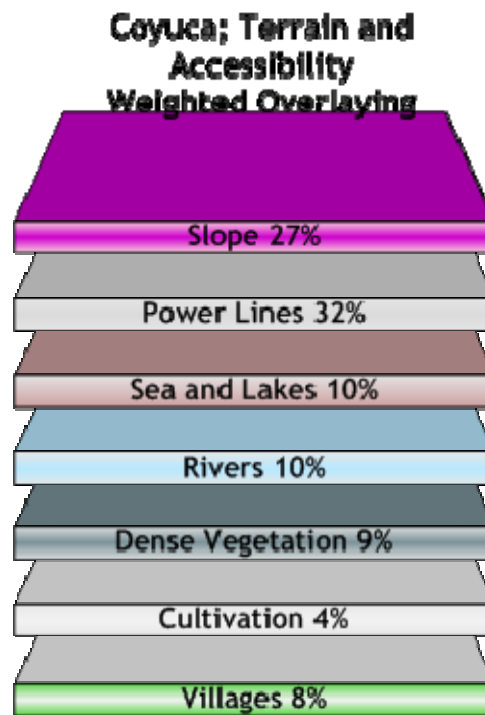
Figure 111. Representation of the Terrain and Accessibility weighted overlaying with weight values assigned

Once these weights are known, the Weighted Overlay tool is executed. The inputs are the seven suitability layers of the Terrain and Accessibility category, the weights in percentage, and the chosen reclassification is from 1 to

9 by 1. The output of this operation is Pot_Drop_Zn and it is the weighted suitability map of the Terrain and Accessibility category, which is illustrated in Figure 112.
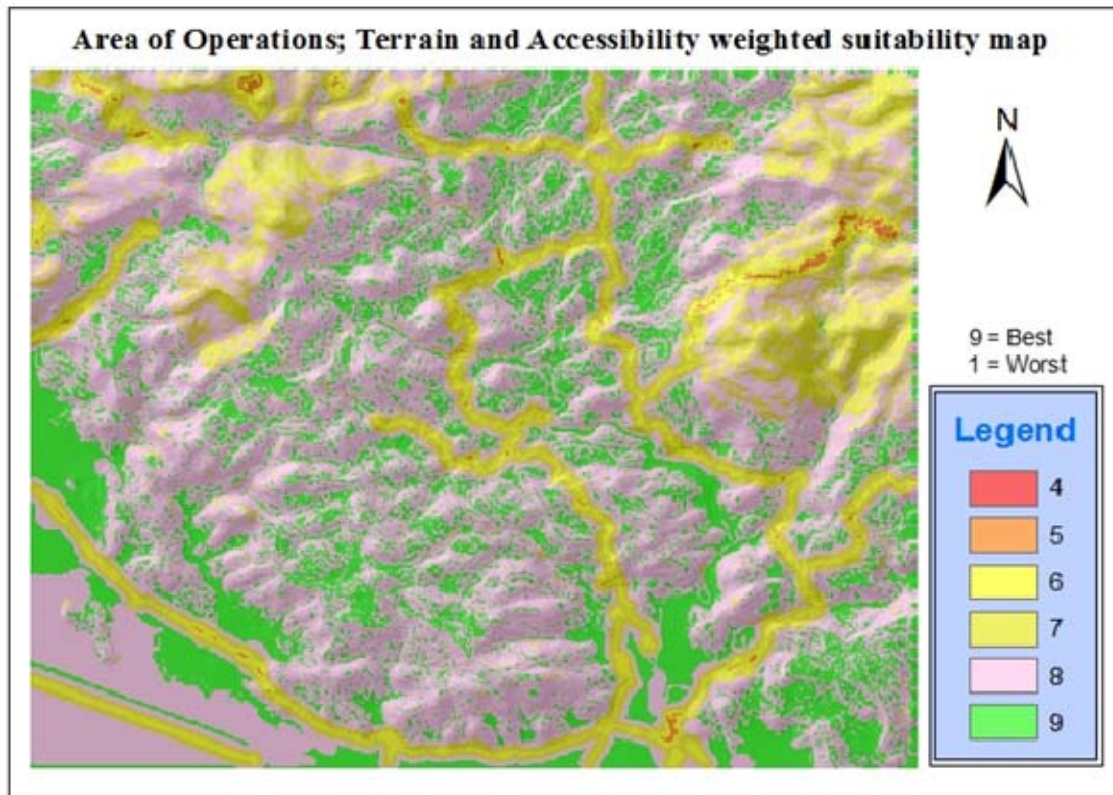
Figure 112.   Terrain and accessibility weighted suitability map; the green areas represent potential Drop Zones (so far)

J.   PARAMETERS, INPUTS, AND OUTPUTS FOR THE CREATION OF THE SUITABILITY MAPS OF THE CATEGORY "ENEMY THREAT" IN THE GEOINT ANALYSIS PRESENTED IN CHAPTER IV

Once the enemy viewshed is known, the GEOINT analyst counts on the required layers to run the distance tools in order to get their respective suitability maps. Hence, the parameters, inputs, and outputs for all of the Enemy Threat layers are:

Feature: Demilitarized Ground Zone (Buffer)

- Minimum suitable distance from feature: 1000 m from the border
- Input for getting the Euclidean distance: demilit_zonebuf
- Output from the Euclidean distance function: disttodemil
- Factor of increment from the linear suitability function: 0.008
- Mdemil1: 1 + (0.008 * disttodemil)
- Mdemil2: CON (Mdemil1 GT 9, 9, Mdemil1)
- Mdemil3 (Demilitarized Ground Zone risk map; output): INT (Mdemil2 + 0.5)

Feature: Enemy Observation Points Fire Range

- Minimum suitable distance from feature: 1200 m (PUO weapons' maximum range)
- Input for getting the Euclidean distance: Enemy_obs_points
- Output from the Euclidean distance function: disttoobsfire
- Factor of increment from the linear suitability function: 0.00667
- Mobsfire1: 1 + (0.00667 * disttoobsfire)
- Mobsfire2: CON (Mobsfire1 GT 9, 9, Mobsfire1)
- Mobsfire3 (Enemy Observation Points Fire Range risk map; output): INT (Mobsfire + 0.5)

Feature: Enemy Observation Point 1 Viewshed

- Minimum suitable distance from feature: 200 m
- Input for getting the Euclidean distance: en_viewshd_1
- Output from the Euclidean distance function: disttoenview1
- Factor of increment from the linear suitability function: 0.04
- Menview1_1: 1 + (0.04 * disttoenview1)
- Menview1_2: CON (Menview1_1 GT 9, 9, Menview1_1)
- Menview1_3 (Enemy Observation Point 1 Viewshed risk map; output): INT (Menview1_2 + 0.5)

Feature: Enemy Observation Point 2 Viewshed

- Minimum suitable distance from feature: 200 m
- Input for getting the Euclidean distance: en_viewshd_2
- Output from the Euclidean distance function: disttoenview2
- Factor of increment from the linear suitability function: 0.04
- Menview2_1: 1 + (0.04 * disttoenview2)
- Menview2_2: CON (Menview2_1 GT 9, 9, Menview2_1)
- Menview2_3 (Enemy Observation Point 2 Viewshed risk map; output): INT (Menview2_2 + 0.5)

Feature: Enemy Observation Point 3 Viewshed

- Minimum suitable distance from feature: 200 m
- Input for getting the Euclidean distance: en_viewshd_3

- Output from the Euclidean distance function: disttoenview3
- Factor of increment from the linear suitability function: 0.04
- Menview3_1: 1 + (0.04 * disttoenview3)
- Menview3_2: CON (Menview3_1 GT 9, 9, Menview3_1)
- Menview3_3 (Enemy Observation Point 3 Viewshed risk map; output): INT (Menview3_2 + 0.5)
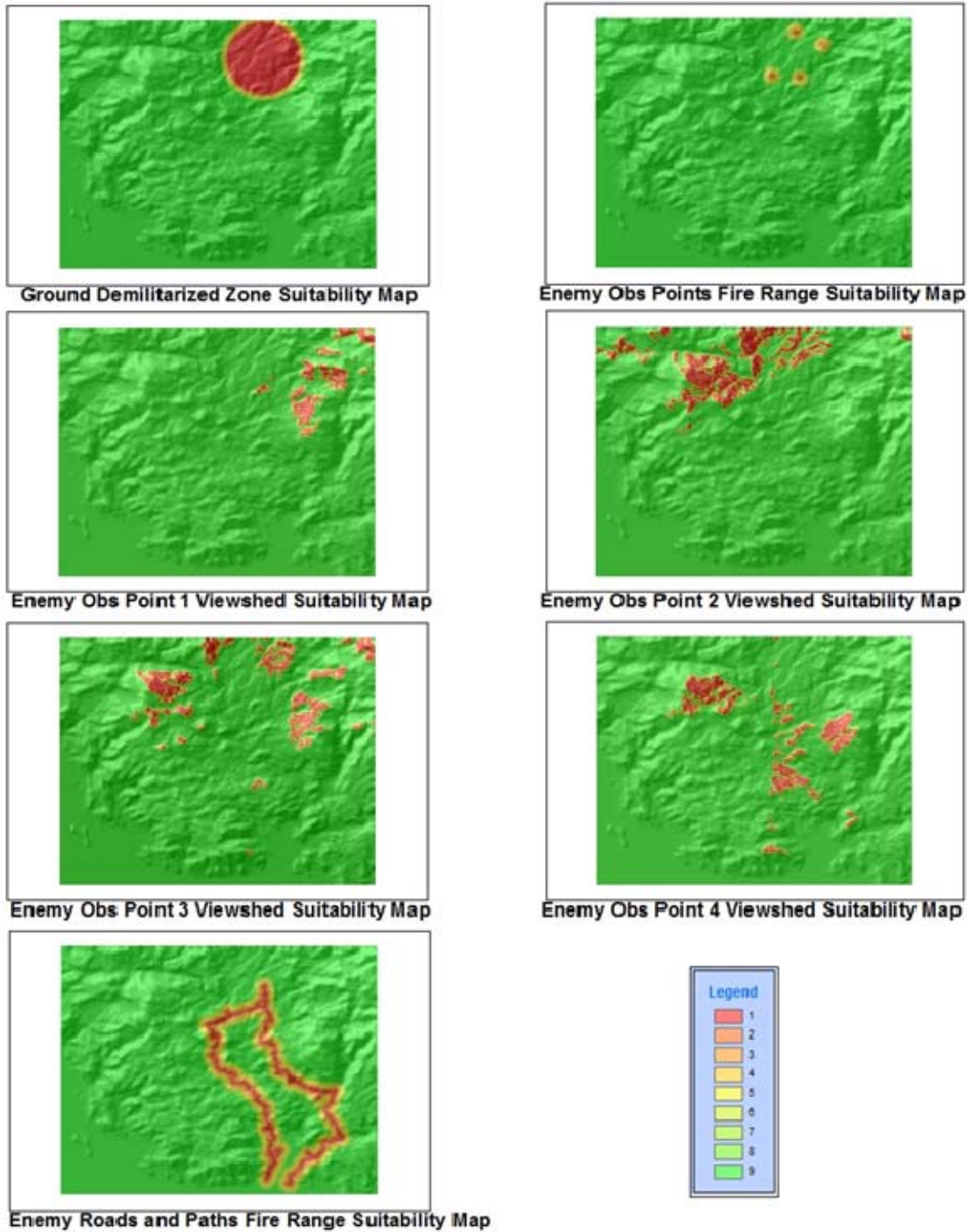
Feature: Enemy Observation Point 4 Viewshed

- Minimum suitable distance from feature: 200 m
- Input for getting the Euclidean distance: en_viewshd_4
- Output from the Euclidean distance function: disttoenview4
- Factor of increment from the linear suitability function: 0.04
- Menview4_1: 1 + (0.04 * disttoenview4)
- Menview4_2: CON (Menview4_1 GT 9, 9, Menview4_1)
- Menview4_3 (Enemy Observation Point 4 Viewshed risk map; output): INT (Menview4_2 + 0.5)

Feature: Enemy Roads and Paths Fire range

- Minimum suitable distance from feature: 1200 m
- Input for getting the Euclidean distance: Enemy_RdsPaths
- Output from the Euclidean distance function: disttoenpath
- Factor of increment from the linear suitability function: 0.00667
- Menpathfire1: 1 + (0.00667 * disttoenpath)
- Menpathfire2: CON (Menpathfire1 GT 9, 9, Menpathfire1)
- Menpathfire3 (Enemy Path Fire range risk map; output): INT (Menpathfire2 + 0.5)

The GEOINT produced in the category of Enemy Threat is illustrated in Figure 113.

Ground Demilitarized Zone Suitability Map

Enemy Obs Points Fire Range Suitability Map

Enemy Obs Point 1 Viewshed Suitability Map

Enemy Obs Point 2 Viewshed Suitability Map

Enemy Obs Point 3 Viewshed Suitability Map

Enemy Obs Point 4 Viewshed Suitability Map

Enemy Roads and Paths Fire Range Suitability Map

Legend

Figure 113.   Enemy Threat Suitability Maps; 9 = Best (green), 1 = Worst (red)

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K. DEVELOPMENT OF ARCGIS FUNCTIONS TO VISUALIZE JUST THE ZONES THAT MEET THE CRITERIA OF SUITABILITY AND AREA FOR DROP ZONES FOR PURPOSES OF THE GEOINT ANALYSIS PRESENTED IN CHAPTER IV

In the analysis, the SOF commander analyzes the GEOINT product and asks the GEOINT analyst to limit the potential drop zones according to the following parameters:

- The Drop Zone cells must have a value of 9 (best suitability value)

- Drop Zone minimum area must be 200 * 200 m = 40,000 m = 4 hectares

- Maximum distance from the objective must be 5,000 m

In this regard, first, the analyst runs the Spatial Analyst> Math> Logical> Less Than tool. The input are the total suitability map (DrpZn_TotSuit) and the value of 9. This operation gives to the cells with values 1 – 8, the value of 1 and to the cells with value of 9, the value of 0. The result is then used as input in the Spatial Analyst> Conditional> Set Null tool establishing the value of 1 for the cells that may result in a "false raster" (cells with value of 0 in the input raster). This operation results in a raster containing just the cells that originally had a value of 9 but now have the value of 1; the other ones have no-value. With this result as an input the next tool used is Spatial Analyst> Generalization> Region Group; the analyst establishes the "eight cells" parameter for generalization. This tool checks for connectivity among cells and then groups them in regions, giving them Ids in the output attribute table. Next, the analyst runs the Spatial Analyst> Zonal> Zonal Geometry establishing that the output measure of the regions must be their "area." The result from this operation is a field in the attribute table of the output raster containing the area of every region in square meters. Then these areas are converted from square meters to hectares by applying the Spatial Analyst> Math> Times tool, which multiplies the cell values by the input factor of 0.0001, and the output raster now has cell values in hectares.

The SOF commander asked for an area of 200 * 200 m as a minimum but the analyst gives a margin to that parameter; consequently, he takes an area of 250 * 250 m (6.25 hectares) as a parameter. With this value, he runs the Less Than tool again and the input is 6.25; the output of this operation is a raster containing regions with an area < 6.25 hectares with cell values of 1 and regions with the desired area > 6.25 hectares with cell values of 0. Next, the analyst runs the Set Null tool, and as a result, the analyst gets an output raster containing only the regions that met the size criteria. The name of that raster is "site7."

In order to have the parameter of distance from the objective to get the desired result, first the analyst obtains a raster with the Euclidean distance from the objective (disttoobjecti). The last step in the process for getting the best drop zones is to run the following map algebra expression "CON (disttoobjecti LT 5000 and site7 > 0, 1, 0)." This means that the regions in a distance to the objective Less Than (LT) 5000 m and with a raster value of 1 (> 6.25 hectares) in site7 would get the output value of 1. Otherwise, they would get the value of 0.

The output of the last operation is the map (DrpZnBest) with the best sites for drop zones meeting the criteria established by the SOF commander. The results are represented in the GEOINT map illustrated in Figure 114.
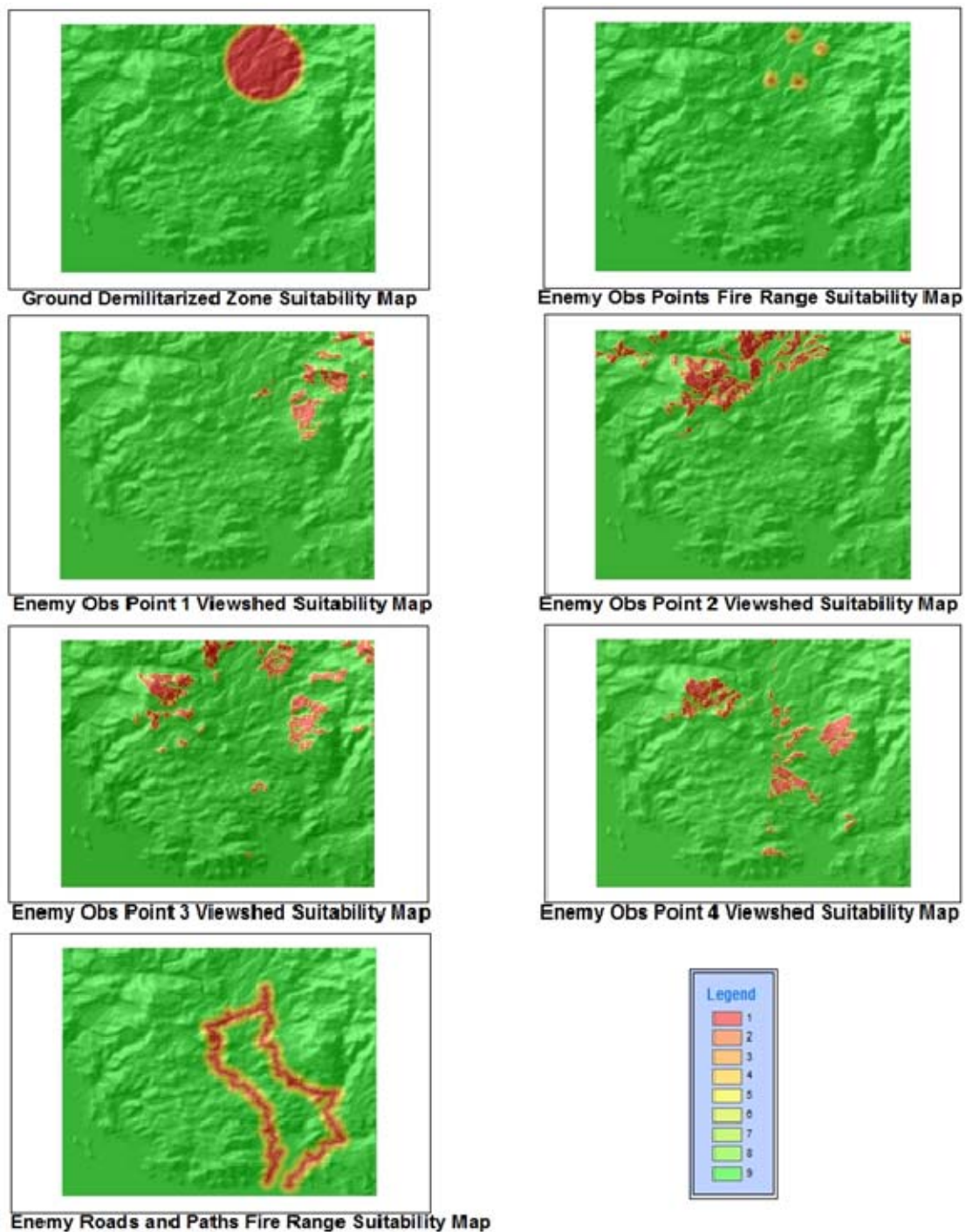
Ground Demilitarized Zone Suitability Map

Enemy Obs Points Fire Range Suitability Map

Enemy Obs Point 1 Viewshed Suitability Map

Enemy Obs Point 2 Viewshed Suitability Map

Enemy Obs Point 3 Viewshed Suitability Map

Enemy Obs Point 4 Viewshed Suitability Map

Enemy Roads and Paths Fire Range Suitability Map

Legend
1
2
3
4
5
6
7
8
9

Figure 114. GEOINT map showing the best sites for drop zone (green) in the area of operations.

L.   BUILDING GIS MODELS TO AUTOMATICALLY DEVELOP A COMBINATION OF ARCGIS FUNCTIONS TO OBTAIN SUITABLE AREAS FOR DROP ZONES AND HELICOPTER LANDING ZONES BY MEANS OF THE MODEL BUILDER TOOL FOR PURPOSES OF THE GEOINT PROCESS PRESENTED IN CHAPTER IV

As an extra task in the GEOINT process, the analyst uses the Model Builder tool in order to make the process of getting a map with the best sites for drop zones easier for future analysts, as well as to have the capability of changing initial parameters and rapidly getting different results in maps or layers. This capability may also allow one to compare the resulting layers one to another in order to discover the influence of the input parameters over the outputs according to the different values assigned. Hence, with Model Builder, the analyst built four sub-models that integrate the whole Drop Zones (DZ) Model:

- 1 DZ Terrain and Accessibility Sub-Model: the inputs for this sub-model are the rasters with the Euclidean distance to the features in this category and the slope raster. Then this model automatically develops all the operations that were applied in the Terrain and Accessibility category, delivering the suitability layer for this category.

- 2 DZ Enemy Threat Sub-model: the inputs for this sub-model are the rasters with the Euclidean distance to the features in this category. Then this model automatically develops all the operations that were applied in the Enemy Threat category, delivering the suitability layer for this category.

- 3 DZ Weighted Sum TerrAcc & Enemy Threat Sub-Model: The inputs for this sub-model are the two outputs from the past two sub-models, which are the Terrain and Accessibility suitability layer and the Enemy Threat suitability layer. It develops the weighted sum of the layers and the reclassification to put them in the scale 1 – 9.

- 4 DZ Best Sites for Drop Zone Sub-Model: The input is the layer obtained from the "DZ Weighted Sum TerrAcc & Enemy Threat Sub-Model" then it executes all the operations developed in this work and returns the best sites for drop zones as output. This Sub-model is based on the "Best Sites" sub-model created by ESRI for HLZ; however, some changes were made to adapt it to the present scenario.

Figure 115 to Figure 118 illustrate the four sub-models in the same order in which they were listed previously. The flow is from top to bottom. The input layers are represented by sea blue ovals; sky blue ovals (in the case of slope) represent input parameters for reclassification; the arrows represent the flow of the process, and orange squares represent tools or functions used in every given step. Green ovals represent outputs from a given operation or tool and, at the same time, they are inputs for the next function. The final output is represented by a purple oval, and the letters **P** outside the features are the parameters that need to be introduced to run the sub-model, as well as the name of the output-raster. The sequence and the operations in the sub-models are the same as those done in this second GEOINT cycle.
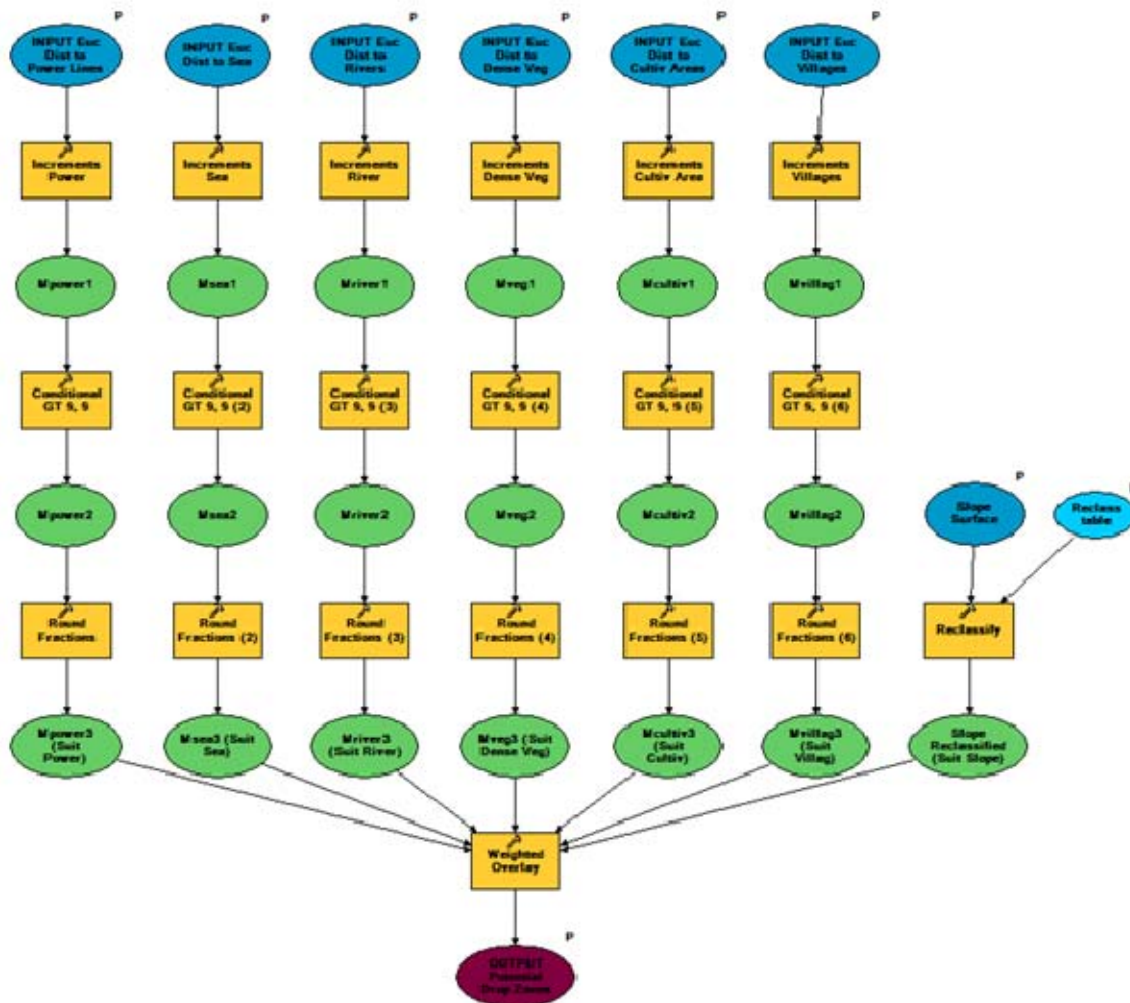
Figure 115. "1 DZ Terrain and Accessibility Sub-Model" graphic-representation

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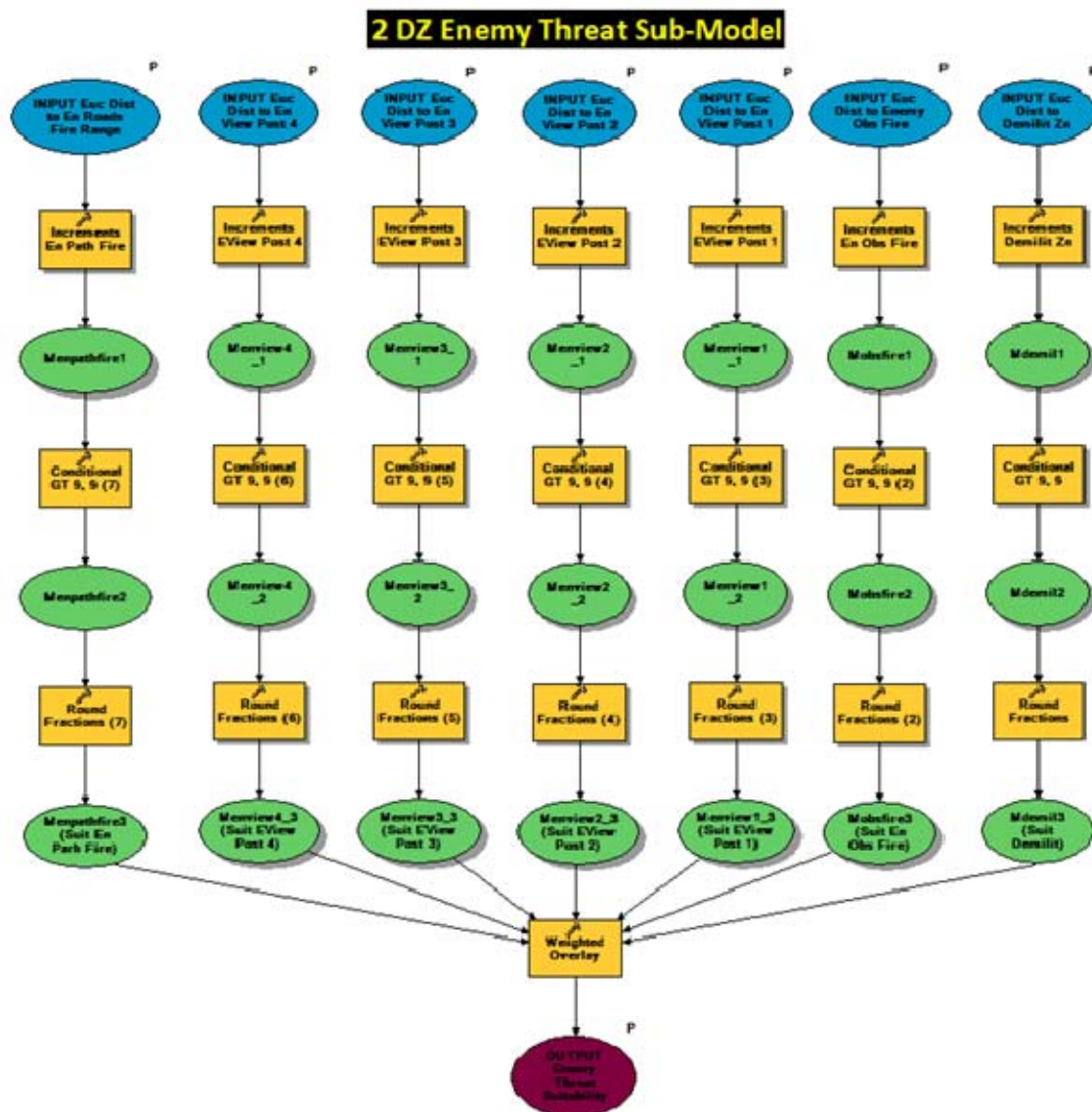
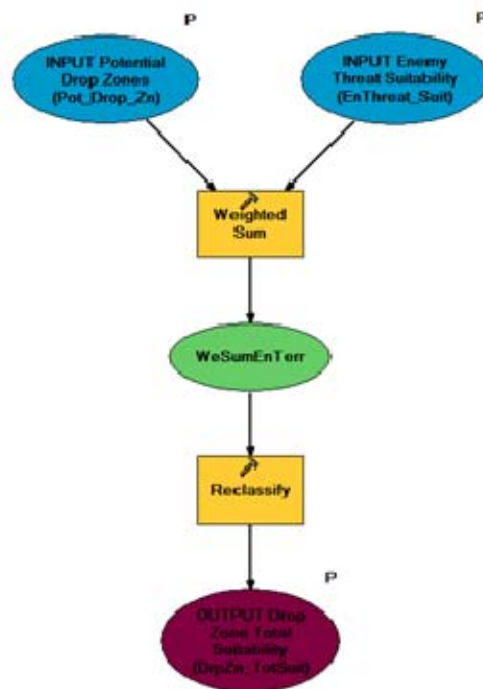**Figure 116. "2 DZ Enemy Threat Sub-Model" graphic-representation**

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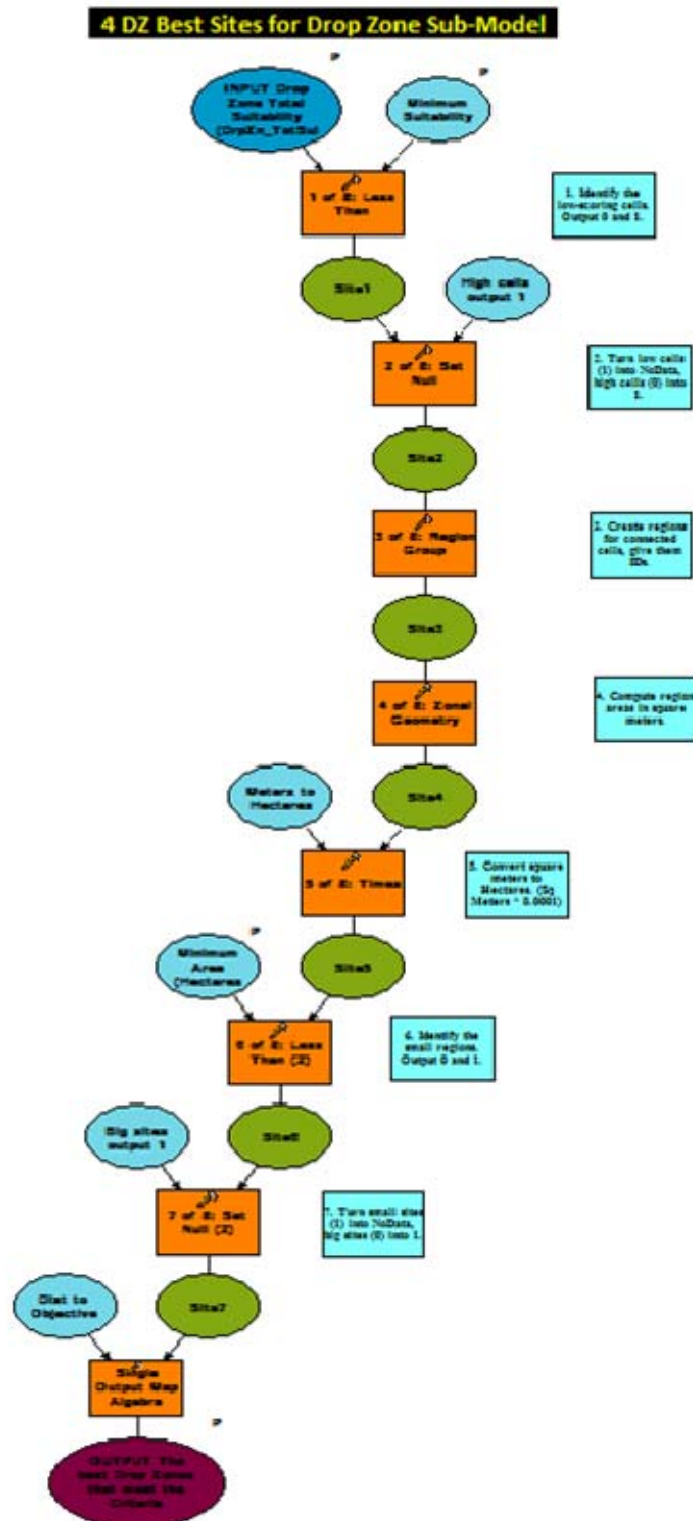**Figure 117. "3 DZ Weighted Sum 'Terrain and Accessibility' & 'Enemy threat'" graphic-representation**
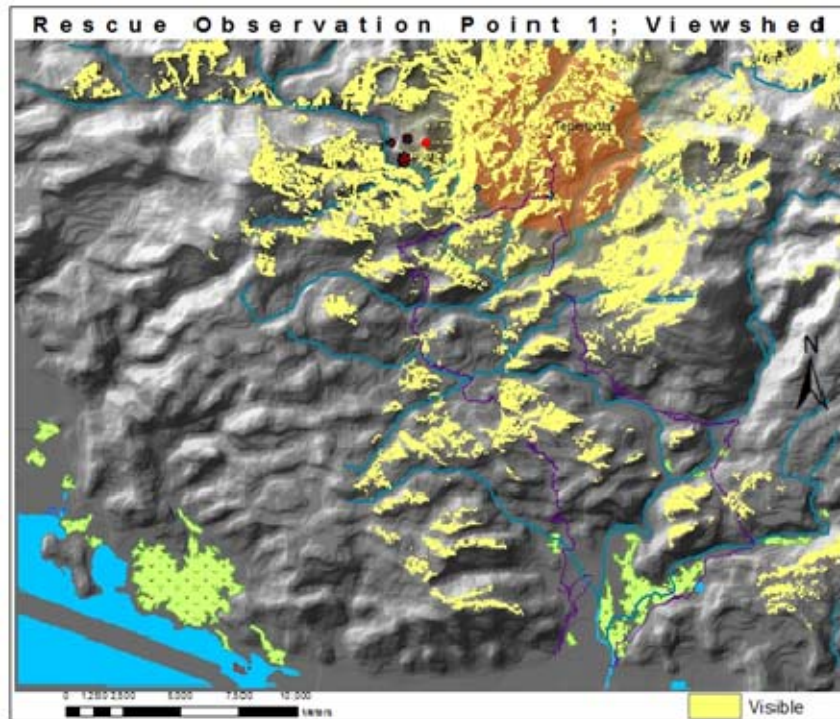
Figure 118. "4 DZ Best Sites for Drop Zone" graphic-representation

M. DEVELOPMENT OF VIEWSHED ANALYSIS BY MEANS OF ARCGIS TO FIND POTENTIAL AREAS FOR THE LOCATION OF OBSERVATION OR/AND VHF COMMUNICATION POINTS FOR PURPOSES OF THE GEOINT PROCESS PRESENTED IN CHAPTER IV


Figure 119.   SOF Unit Observation Point 1 viewshed

By analyzing observation point 1 viewshed (obs1_view), the SOF commander determines that it has good visibility. However, for VHF communication purposes, the point's viewshed does not cover the HLZ; consequently, the GEOINT analyst is asked to find potential sites, and to find which viewshed would cover both rescue observation point 1and the HLZ. Therefore, this site includes the second observation point.

In this regard, the HLZ viewshed (hlz_view) is created and with the map algebra expression "obs1_view AND hlz_view" just the areas covered by both viewsheds are returned (hzl_obsComb) with a cell value of 1. Then, by

visualization, the SOF commander compares the enemy viewsheds with the one just obtained and assigns observation point 2, outside of the enemy viewsheds.

Next, a viewshed for the Navy ship in the operation is developed to discover if the operational commander is going to be able to communicate with the Rescue Unit by means of VHF from the ship. In this regard, the analyst inputs the height of the ship's antenna (15 m) when running the viewshed tool, but the result shows that none of the two rescue observer points fall into the viewshed range nor does the ship fall into any of the viewsheds of the two rescue observer points. Consequently, it is necessary to look for a location that will work as a communications bridge. To know the possible locations for this point, the GEOINT analyst develops an operation similar to the one executed when looking for observation point 2. Hence, the analyst combines the ship and the observer point 1viewsheds to get the intersection. Once the areas of intersection are presented, the SOF commander chooses one of them on which to locate the observation point and this is designated as observation point number 3, for the Rescue Unit. Once the three observation points are known for the rescue unit, the GEOINT analyst presents a map with their viewsheds, Figure 120.
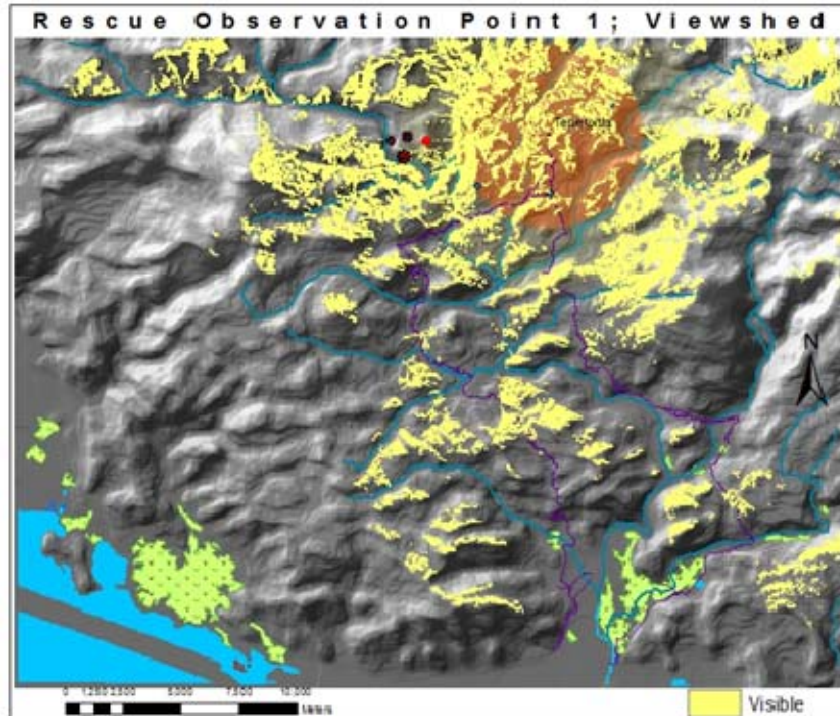
Figure 120. SOF Observers Viewshed Map

N. **OBTAINING LESS COST PATHS FOR THE RESCUE FORCE ON THE GROUND FOR PURPOSES OF THE GEOINT ANALYSIS PRESENTED IN CHAPTER IV**

During the GEOINT process, the SOF commander asks the analysts to find two less cost paths for the rescue force. One from the DZ to the Objective and the other one from the Objective to the HLZ. Less cost path differs from the shortest path in the fact that the first takes into account not only distance but also many other factors (as many as the analyst considers) that affect the movement from one point to another, such as slope, vegetation, soil, and so on. In order to execute the operation the first step is to get a cost raster; in this case, the analyst already has one cost raster, which is the DZ Total Suitability layer, which contains all the factors affecting the area of operations. In this case, the

layer needs to be reclassified   in terms of suitability and the analyst needs a layer in terms of cost, which is found by reversing the values with the reclassify tool. The output could be named total_cost.

Then, with the DZ feature class and the total_cost layers as inputs in the Spatial Analyst> Distance> Cost Distance tool, the analyst gets the cost distance and cost direction layers, which then have to be the inputs in the Spatial Analyst> Distance> Cost Path tool., But first the starting point (DZ centroid) needs to be selected. The output of the last operation is the less cost path, which is a raster that can be converted to a polyline to make it more visible. A similar process is made to get the less cost path from the objective to the HLZ, Figure 121.
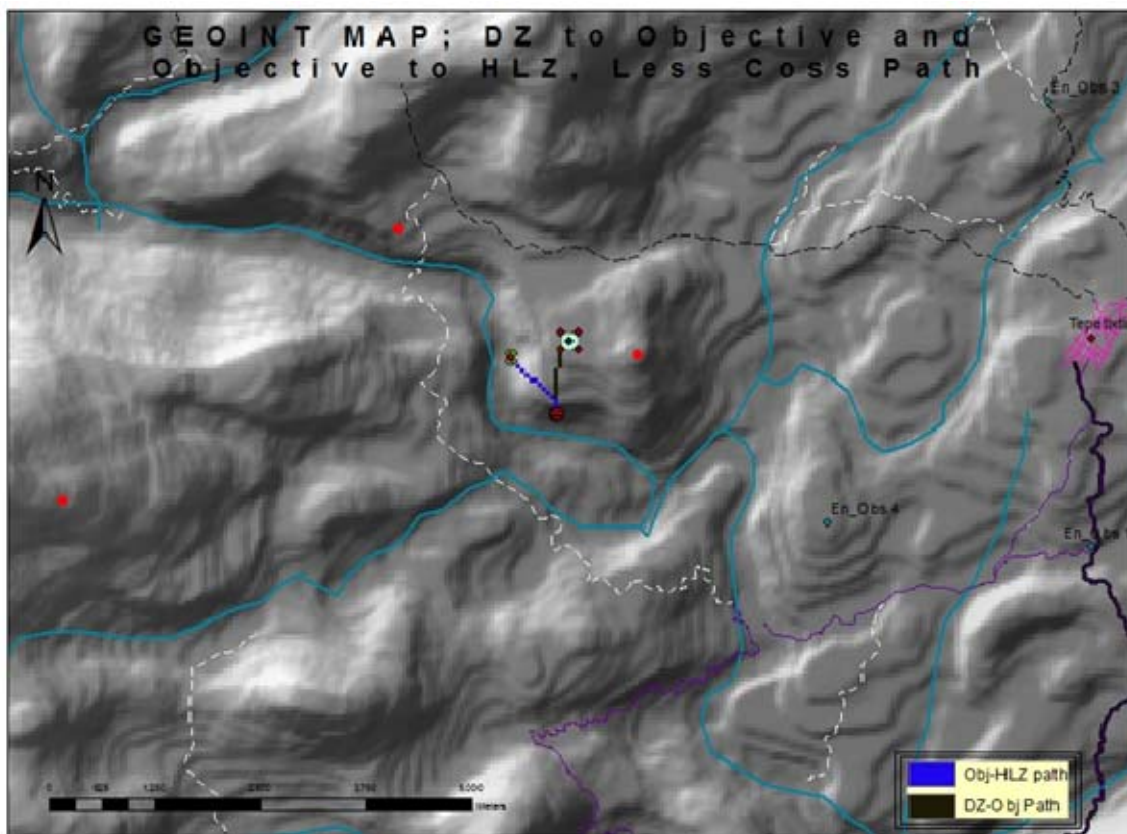
Figure 121. Less Cost Paths for the SOF Rescue force

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